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FINAL FRONTIER

The Magazine of Space Exploration

September/October 1990

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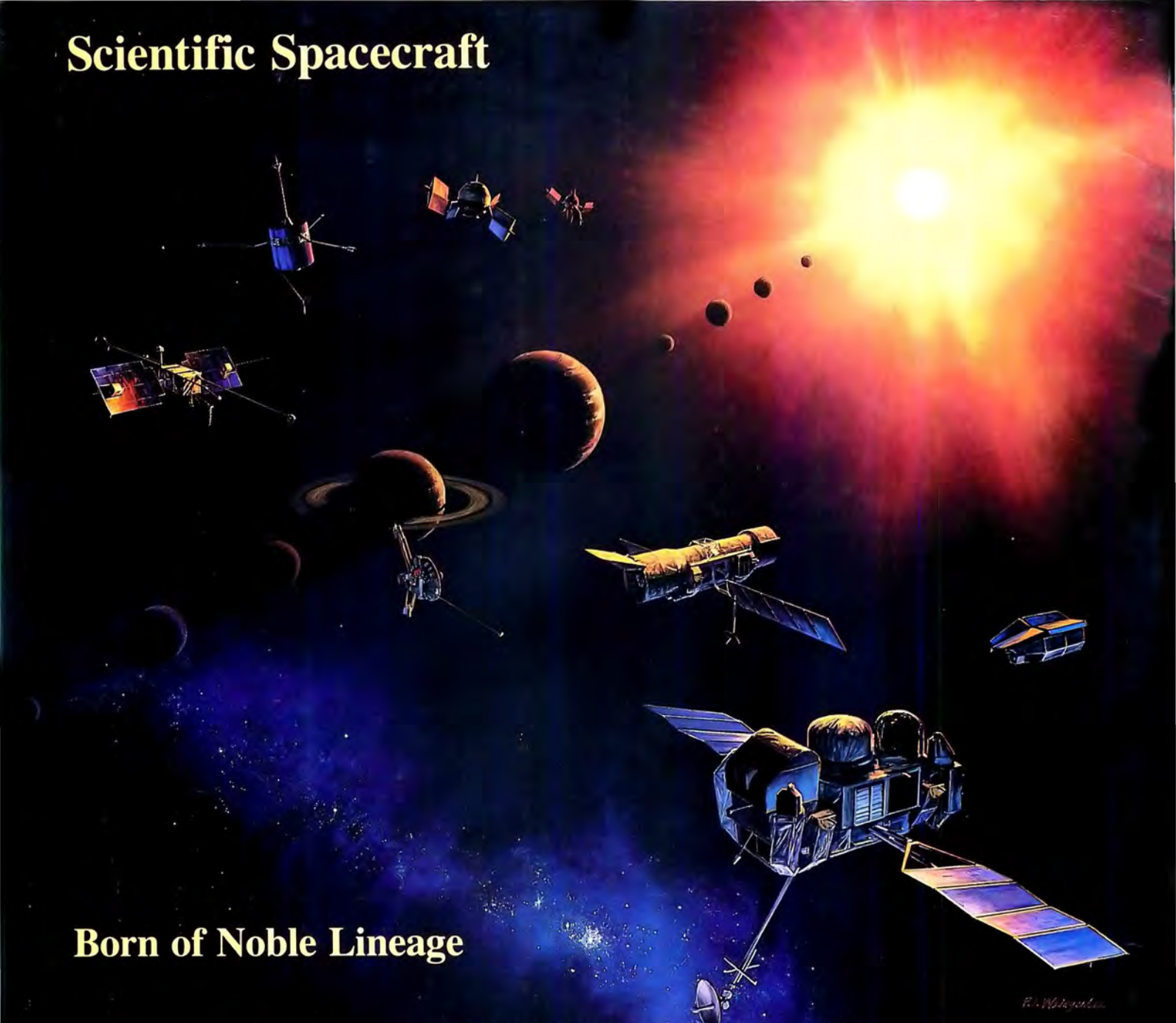

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DEPARTMENTS

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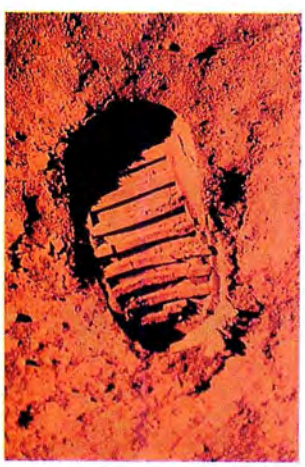
On the cover: A human footprint on the Red Planet? A worldwide effort is building to make that incredible dream a reality. See our special report beginning on page 25.



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FEATURES

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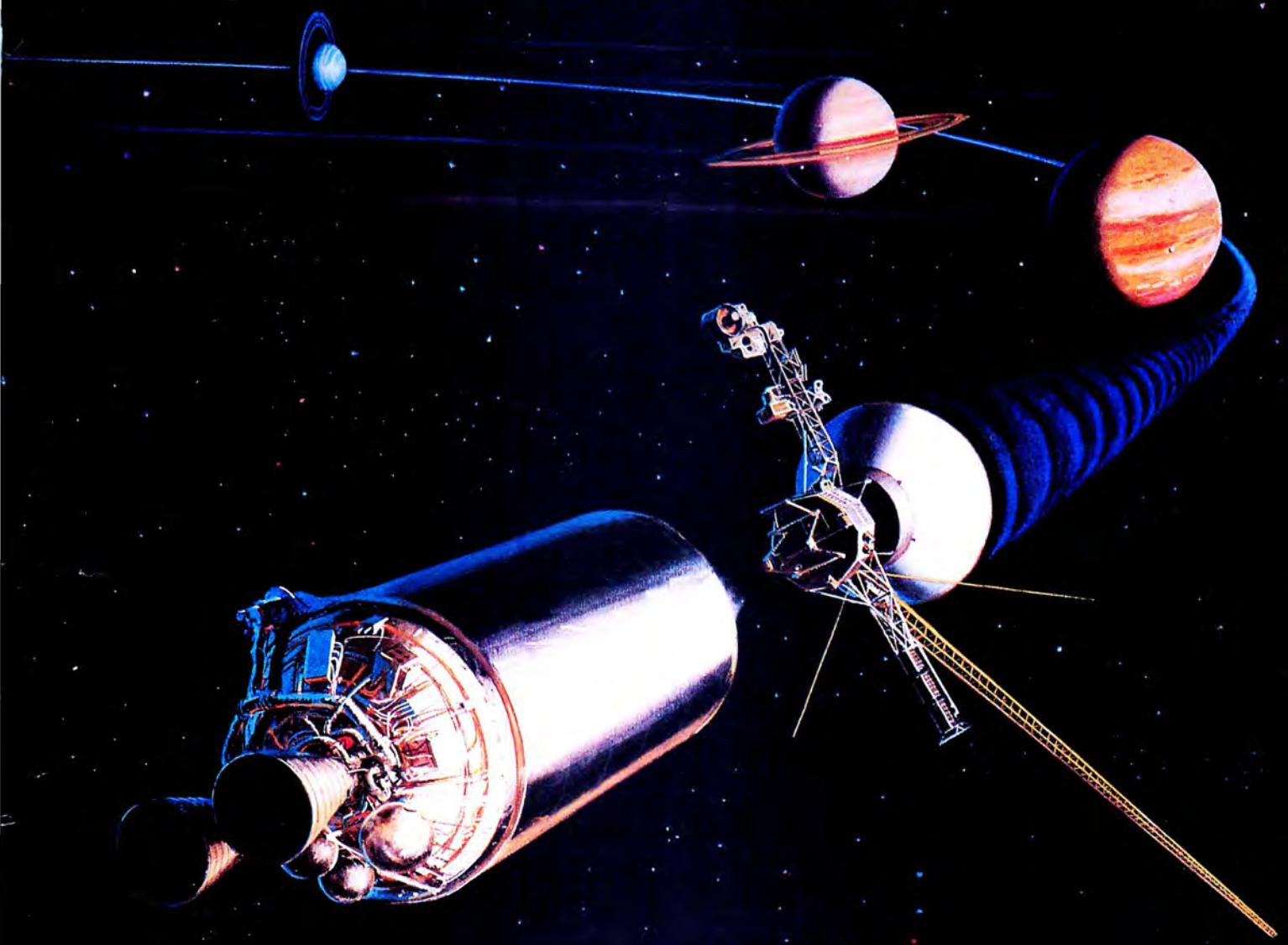

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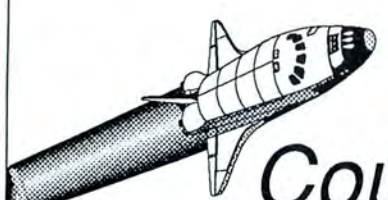

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SAIC: Preparing for the New Space Initiatives

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- President George Bush at the 20th anniversary of the Apollo Moon Landing

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Letters

Nelson In Baikonur

About the photo in Pinky Nelson's article on "An Astronaut in Baikonur" (May/June 1990) that shows him testing a launch couch: Never mind the launch couch; get a load of that Persian carpet.

Henry Morgenstern
Las Vegas, Nevada

I hesitate to take issue with someone who's been there, but I think Pinky Nelson got his launchpads mixed up.

The Proton launcher was not used to launch Sputnik, Vostok and Soyuz, so it could hardly have been the Proton pad he visited. I suspect also that it wasn't a Proton booster he was looking at in the integration building, but a Soyuz.

These points notwithstanding, it was a fascinating article, particularly his evaluation of the Soviet manned maneuvering unit.

David J. Maclennan
Vice President, New Zealand Spaceflight Association

Vitamin G

In light of your call for new concepts that might facilitate a mission to Mars or beyond, allow me to present my ideas on the problem of long-term weightlessness. The Soviet space station missions indicate that exercise alone cannot maintain skeletal and cardiovascular health in a zero-gravity environment. Gravity must be viewed as a staple like air, food and water that must be supplied by artificial means.

The proposals to create a gravity-supplying dense mass in flight, while not forbidden in physics, are beyond our present capabilities and are likely to remain so for the Mars mission.

The simplest way to create gravity in a manned vehicle is through acceleration or deceleration. One strategy would be to shift the vehicle repeatedly between an extended acceleration or deceleration phase of 32 feet per second, which would provide the crew with an earthly 1-g force. Another would be to set the vehicle on a serpentine course and let centripetal acceleration provide the gravity. The engineering needed for these schemes would be significant but manageable. The extra energy and flight time demanded could be minimized once bioscientists determine how much time humans need each day in an Earth-like gravity to maintain their health.

Laurence S. Gluck
Thousand Oaks, California

Joint Mars Mission

The article by Yuri Semenov entitled "Together to Mars: A Proposal" (May/June 1990) was well written and thought provoking in its acknowledgement of today's economic realities. I would note, however, that Semenov's comments about a joint Mars venture between the United States and the Soviet Union suggest the view of a scientist rather than a politician. Both sorts, in their own way, tend to ignore the harsh realities of today's world.

The concept of cooperation, in scientific terms, makes perfect sense; but politicians work in a world where absolute perfection is nonexistent. Given this fact, the reader has to wonder whether a joint venture could ever be developed by the two superpowers. If only that decision *could* be left to the scientists!

Politicians control the purse strings in both countries—and political concerns usually win out over any joining of minds, no matter how beneficial to humanity. Politicians must learn to acknowledge what is implied in Semenov's proposal: The future of this planet hinges on the development of products that can only be manufactured in space.

Keep up the good work on reporting the day-to-day details of space exploration and making it interesting.

Wesley Glenn Johnson
Waycross, Georgia

Women in Space

Letter writer David C. Morrow (July/August 1990) of the Men's Rights Association exhibits the kind of male-chauvinist mentality we need to eradicate from Earth. While the nation did focus much of its grief over the Challenger disaster on Christa McAuliffe, it was principally because she was a teacher, not a career astronaut, and because so many young students were watching the launch when the disaster occurred. That she was a woman was clearly a less important factor: The death of the other female astronaut, Judith Resnik, received no more coverage than the deaths of the male astronauts.

Men have generally used arguments that women are delicate and need to be protected in order to exclude them from higher-paying and higher-status positions. For example, some judges prohibited early women lawyers from practicing in courts, allegedly because they were too "delicate" to deal with nasty legal matters. Women have shown themselves fully capable of bearing the heaviest responsibilities.

If given the chance, women will hold up their responsibilities in space. Effective space exploration will rest on men and women working together as partners, not adversaries.

Allen Meyer
Phoenix, Arizona

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The Observatory

Is NASA Dead?

It's not where the agency went wrong, but where it's headed that counts. ■ *By Tony Reichhardt*

The shuttle leaks. The Hubble telescope won't focus. The space station needs redesigning. What happened, the public wants to know? Who's to blame?

There are even better questions, though—like where is NASA headed now? More fundamental still: Why?

The answer *should* be to explore space, to learn something about the Universe we didn't know already. In the face of "what-have-you-done-for-me-lately" questioning by Congressional budget committees, that rationale may seem soft. But it's the only one that is always, irreducibly true.

Has NASA lost sight of that basic mission? As an institution, it seems more interested lately in engineering projects than in exploration. Most of its energy goes to keeping the shuttles flying and the space station funded. Perhaps the agency is so shell-shocked from years of budget wars that it has forgotten what it's fighting for.

Contrary to what NASA administrators may think, it's entirely possible to spend more money in space and get less for it. One good way is to keep expanding bureaucracy while conducting endless paper studies of Mars missions that no one intends to launch. The proof of our success in space will not be in how much money we spend, but in how many new places we go and how many new things we learn.

The NASA that aimed for the Moon 20 years ago had a clear mission, a yardstick against which all its efforts could be measured. Today's space program is more subtle, more diverse, more challenging by far. A decades-long program to move civilization out into the Solar System will involve many nations, federal agencies and private companies. It's hard to know where to begin, and it will be harder still to keep our focus sharp.

The best way to keep that focus is to continually ask the primal question: *Why?* NASA engineers deal with the *how* and *what* of making their machines work. Congressional committees and news reporters ask only *how much* will they cost, and *when* will the leaks be fixed. No one asks why.

Why build a space station? For commercial research? If so, it makes more sense to start with a small, commercially developed workshop like the Industrial Space Facility. Is it to house eight astronauts? Expensive home. A stepping-stone to the Moon and Mars? Good. But until we start planning those missions in more detail, how do we know Freedom is the right stepping-stone?

This is the biggest question facing NASA today. Recent agency studies suggest that the current plan for building the station is impractical, because it requires too much maintenance by space-walking astronauts during assembly. Some redesign will almost certainly be necessary, and the price tag is sure to go up.

Instead of seeing this as a threat to Freedom's political future, NASA should take this opportunity to ask the all-important why, to make sure *this* space station really is necessary and well-suited to the task of supporting a Moon/Mars mission. If not, change it or build something else.

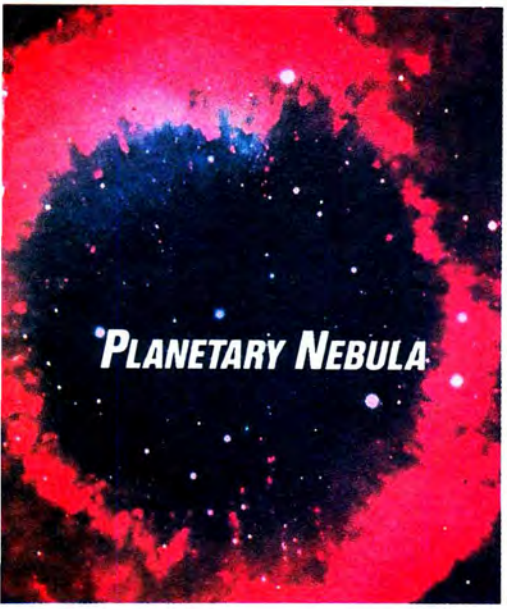
Freedom was originally designed to satisfy many different users at a time when the U.S. space program was without clear direction. Now President Bush has pointed us toward the Moon and Mars. But the space station already has inertia of its own, and the danger is that it will end up competing with the President's grander vision by absorbing all of NASA's time and money for the next 20 years and stifling any plan to reach Mars cheaper or sooner. Already there are signs of conflict between the space agency and the National Space Council: The Council seeks innovation and economy, while NASA stubbornly stays the course.

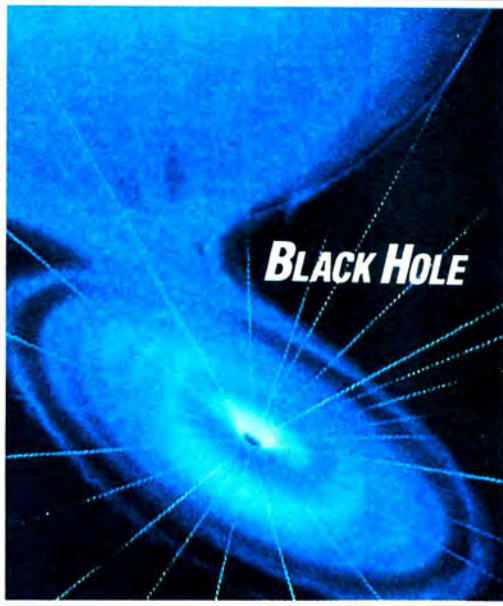
If NASA wants to keep the public trust, it needs to weigh every one of its current programs—Freedom particularly—not in terms of institutional self-interest, but in whether it is the leanest, most efficient means of advancing the mission of space exploration. NASA needs to ask *why,* and not flinch from honest answers.

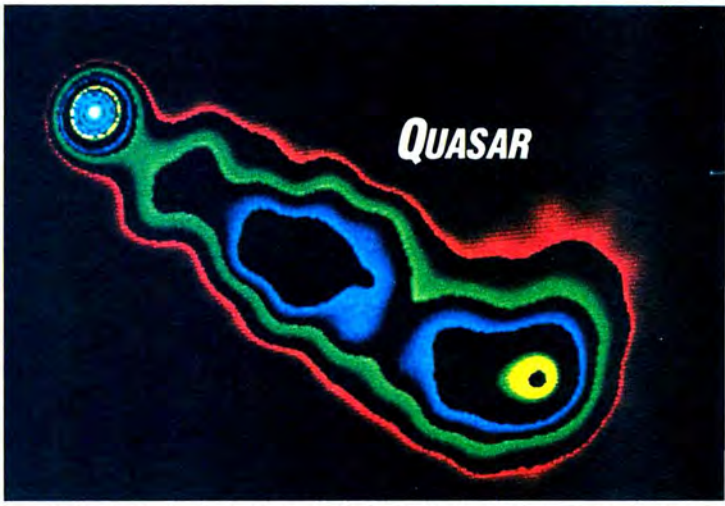
Is that too much to ask of a bureaucracy that has its hands full with day-to-day engineering operations? If so, then let someone else—a new agency, perhaps—chart our course to the Moon and Mars. But I suspect there are plenty of people working at NASA today who'd love to be exploring space again. They have ideas, they have energy. They only need the chance.

Tony Reichhardt is the editor of Final Frontier.

DISCOVER FIVE OF THE MOST AMAZING OBJECTS IN THE UNIVERSE.







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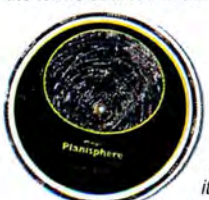

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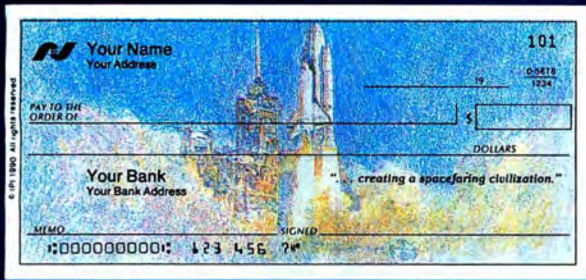

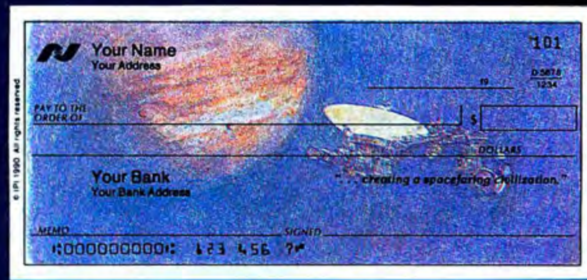

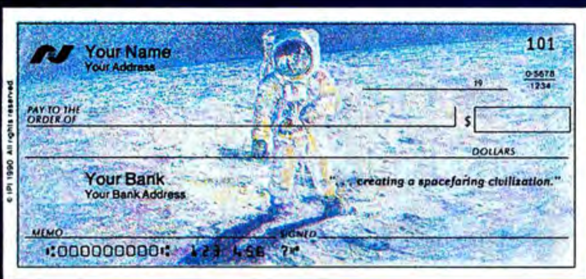

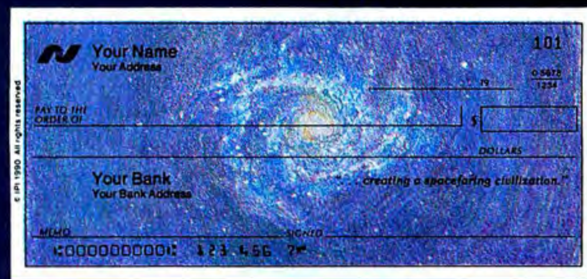

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NOTES FROM EARTH

Spinning Toward Mars

The one-winged Samara would be simple and elegant, more like a twirling maple seed than a spacecraft. With no fuel requirements or moving parts, the tiny probe would take high-resolution photographs of Mars as it spins downward through the thin atmosphere, buoyed by aerodynamic forces. Or so goes a plan proposed by James Burke of NASA's Jet Propulsion Laboratory.

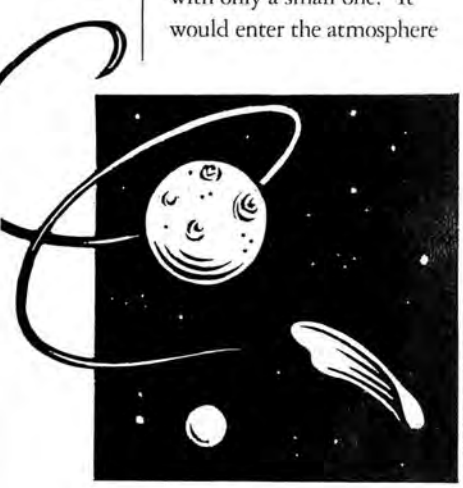
The idea for Samara (which is a generic name for winged, maple-type seeds) goes back to the Ranger probes of the 1960s, Burke says. But unlike the Rangers, which crashed into the lunar surface on kamikaze photography missions, Samara would take advantage of a spin-scan imager to take high-resolution photos of Mars as it slowly descended to the surface.

While the Viking landers that photographed the Martian surface in the 1970s required large heat shields, the Samara could manage with only a small one. "It would enter the atmosphere as a hypersonic arrow and slow to subsonic speeds before beginning to spin," Burke says. A smaller heat shield means less weight and size. In fact, Samara is yet another creative idea for what are coming to be called "micro-spacecraft."

"Samara has a half-meter wingspan and its mass is less than a kilogram," Burke says. "You could carry a bunch of them into Martian orbit." He envisions a fleet of probes that could be used for a survey of the Red Planet by a human expedition. It's possible that each probe could be manufactured for about $10,000 or less, he says.

Even though the idea for the Samara probe generated enough interest to earn a grant back in 1987 (from the Caltech President's Fund, to test the basic aerodynamic concept), it has failed to capture widespread interest. One reason may be the lack of official interest in micro-spacecraft, at least to date. Unfortunately, says Burke, "Micro-spacecraft have yet to find their place in space exploration."

—Joseph Baneth Allen



ILLUSTRATIONS BY SUSAN NEES

Earth Orbit —by Balloon

An American pilot, a Russian cosmonaut and a British entrepreneur plan to attempt the world's first balloon trip around the globe in November.

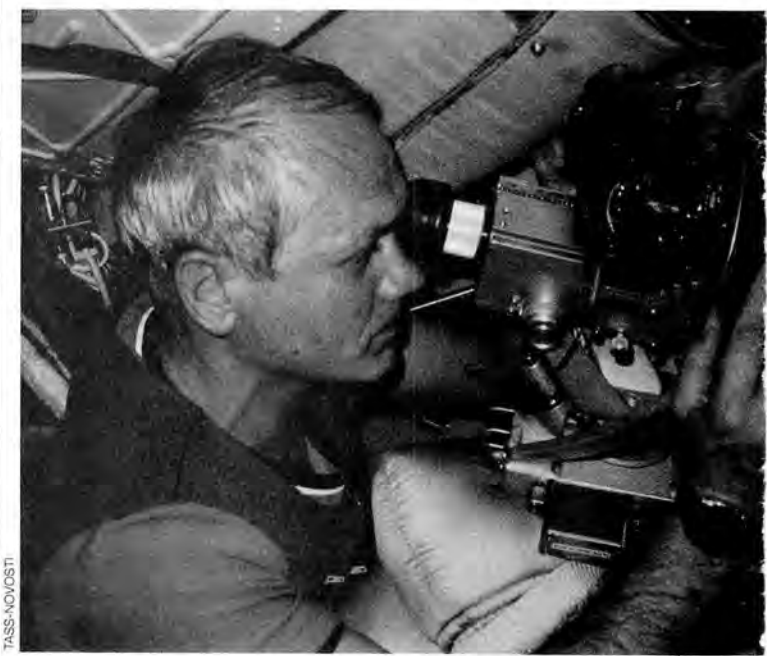
The flight is no joint mission to Mars, but world-record balloonist Larry Newman thinks his Earthwinds Project could launch more cooperative ventures between space agencies in the United States and the Soviet Union.

Besides setting the world distance record for a balloon, the history-making flight will help NASA and the Soviet space agency Glavkosmos learn more about the jet stream.

"Our heart is in it because it's aeronautical exploration of the finest kind, and that's our job," said Charles Vermillion, who will manage NASA's participation from the Goddard Space Flight Center in Greenbelt, Maryland.

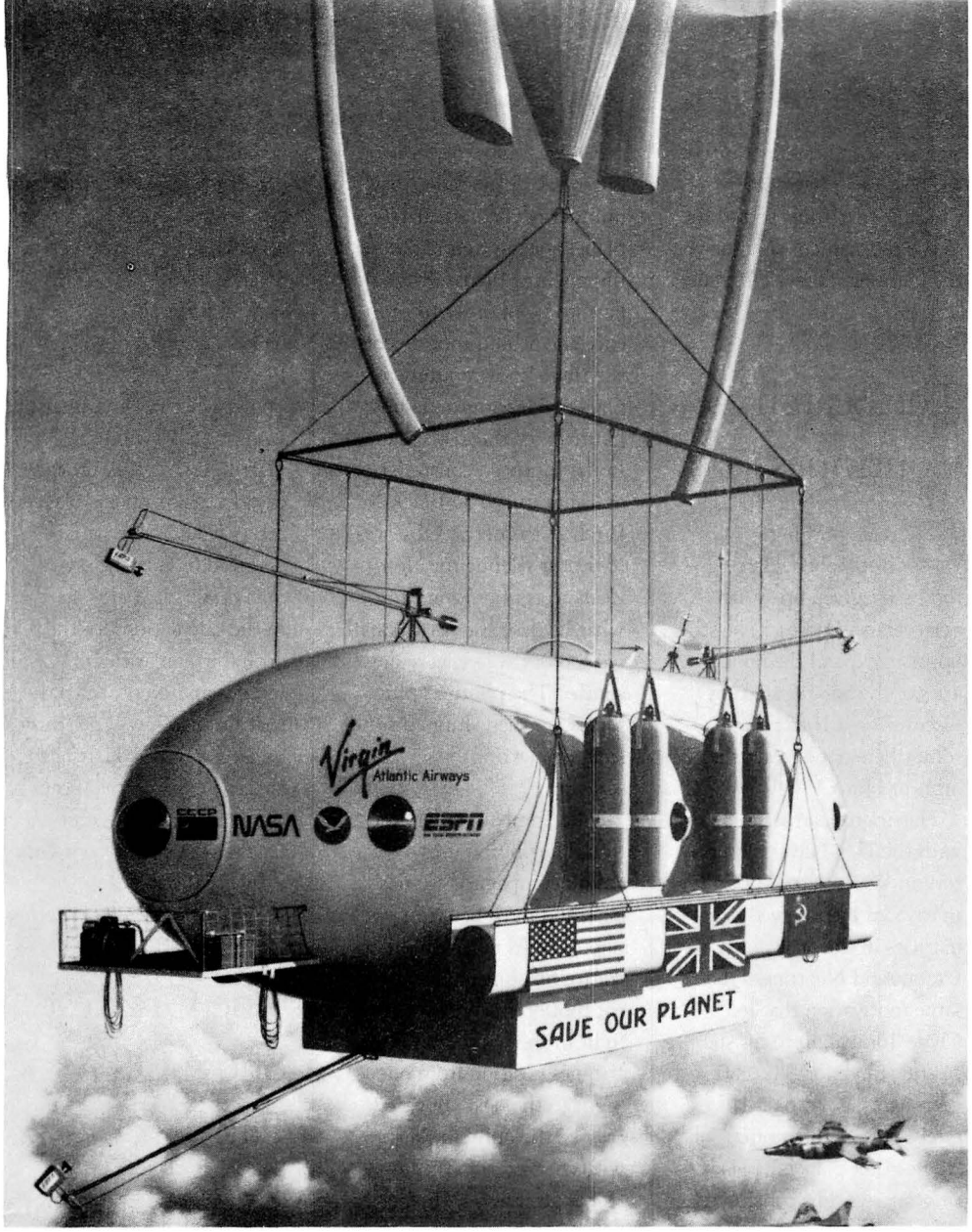
"We see the opportunity to do some excellent science that couldn't be done by an aircraft or an unmanned balloon," Vermillion said.

The $2 million helium balloon will carry a package of instruments to study that



TASS-NOVOSTI

Vladimir aloft: the Soviet cosmonaut prepares for an astrophysical experiment during an earlier mission onboard Salyut 7. Dzhanibekov will be part of a crew attempting to circle the Earth in a balloon.



VIRGIN ATLANTIC AIRWAYS

The high-tech capsule that will carry the global balloon crew is a far cry from the open gondolas of yore.

turbulent channel of air where airliners zoom and pollution floats. As the balloon rides the jet stream, seven miles up, "What you're going to see is essentially one large piece of pollution moving around Earth," explained Newman, the only person to have crossed both the Pacific and Atlantic oceans by balloon.

Joining Newman will be Vladimir Dzhanibekov, 47, the world's most experienced cosmonaut with five spaceflights (only NASA's John Young has flown more times). A major general in the Soviet air force, Dzhanibekov last visited Earth orbit on a June 1985 mission to rescue the Salyut 7 space station.

Newman sought out a cosmonaut because the idea of flying with a Soviet citizen appealed to him. "I didn't know they were going to give me their number-one guy," he said. "The more we work with the people in the Soviet Union, the better our relationship with that country gets."

Underwriting the project and along for the ride is Richard Branson, 39, founder and chairman of a London business empire that includes Virgin Atlantic Airways and Virgin records.

Other sponsors, according to Newman, include Allied Signal Aerospace Corporation, providing $700 million worth of equipment; Newman's own employer, America West Airlines; and ESPN, the cable sports network that will broadcast the trip.

NASA and Glavkosmos will provide technical support for communications and navigation in return for scientific data that will be relayed from the balloon to the ground by satellite in real time.

The three plan to take off from the Loral Airdock in Akron, Ohio, sometime in November when the weather is right, and fly northeast. Newman figures it will take 12 to 21 days to cover 18,000 to 22,000 miles, depending on the weather. He expects to cruise at 75 to 100 miles per hour at altitudes between 35,000 and 45,000 feet.

Their gondola is a pressurized, computerized, 24-by-10-foot capsule, tethered to a translucent, 140-foot-diameter balloon. The whole system is more than 300 feet tall.

The balloon will soar over Newfoundland and the United Kingdom, Europe and the Soviet Union, north of Japan and across the Pacific, then across the United States before landing somewhere east of Akron.

—Beth Dickey

Lofty Debates

Resolved: That the U.S. government should significantly increase space exploration.

This fall, the debate on America's role in space moves from the editorial page to the classroom. Students across the land will be arguing the cases for and against increasing the

NOTES FROM EARTH

pace of space exploration—this year's chosen topic for high school tournament debaters.

Even though the debates will be exposing the blemishes behind the beauty of America's space effort, advocates are in orbit over the attention that will be given to their pet project.

"These kids are tomorrow's leaders. They ought to know as much as they can about space now," said David Brandt, program director of the National Space Society in Washington, D.C.

"Maybe they won't grow up to be debaters, but maybe they'll go on to become NASA engineers or aerospace employees," said Brandt, whose organization is providing some of the reference material the students will use in preparing their pro-or-con arguments for competition.

Among the other contributors are NASA, which promised materials and money, and aerospace giant General Dynamics, which donated 5,000 copies of a full-color book on future space exploration missions.

"Here's a chance to raise the consciousness of a great many young people across the country," said Richard G. Fawcett, debate coordinator for the National Federation of State High School Associations.

Of 10,000 teams across the country, 190 are expected to survive a 17-debate elimination series and qualify for the national competition in Chicago next June, according to the tournament sponsor, the National Forensic League.

—Beth Dickey

The Search Continues

So far, nothing. But Robert Harrington hasn't given up. With perseverance and luck, he still hopes to expand the boundaries of the Solar System by discovering a 10th planet somewhere out beyond the orbit of Pluto.

Harrington, an astronomer with the U.S. Naval Observatory in Washington, D.C., is motivated by observed irregularities in the orbits of Uranus and Neptune—the same motivation that led Clyde Tombaugh to his successful search for Pluto 60 years ago. "We can't accurately predict the motions of [these outer planets]," Harrington says. His conclusion—which some astronomers dispute—is that an unseen body is perturbing their orbits.

A Naval Observatory computer has simulated a number of theoretical 10-planet solar systems to determine where Planet X would have to be in order to influence the orbital motions of the three known outer planets. Harrington is now hunting for the 10th planet in the southern constellation of Centaurus. The Black Birch Astrometric Observatory near Blenheim, New Zealand is photographing what he describes as a "small section of the sky, very far south." The photographic plates are then shipped stateside for Harrington's scrutiny.

Like Tombaugh before him, Harrington uses a "blink comparator" to flash back and forth between two photographs taken on different nights, causing an apparent motion if any point of light in the photographs changes position from one night to the next. But that may be the only similarity with the search for Pluto, Harrington notes. "Planet X will be three to five times the mass of the Earth and is about three times as far away as Uranus and Neptune," he speculates. He believes the planet is in a 1,000-year orbit around the Sun, tilted 30 to 40 degrees to the plane of the Solar System.

While Harrington thinks he has narrowed down what Planet X will be, he also knows what it won't be. "It won't be a brown dwarf," Harrington says. A brown dwarf's effects on the planets' orbits would have long been detected by now, he says.

It's possible there's an error in the calculations for the orbital irregularities of Uranus and Neptune, and that his search will not turn up a new planet, Harrington concedes. But in the meantime, he's patiently waiting for the next plates from New Zealand.

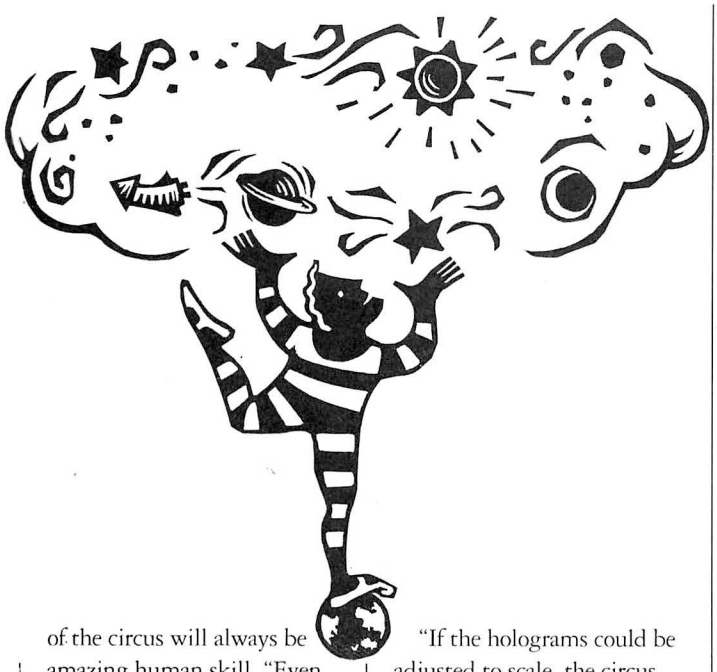
—Joseph Baneth Allen

The Greatest Show Off Earth

For more than a century it's been billed as the Greatest Show on Earth, but someday that billing may not be quite grand enough. According to some forward-looking circus pros, the three-ring big top of the future may be headed for zero-g.

Hovey Burgess, an instructor of circus skills at New York University, and Kenneth Feld, producer of the Ringling Brothers and Barnum and Bailey Circus, have already started thinking about how to keep this American institution one step more astounding than a surprising new competitor—the space program.

Feld, who oversees a circus dynasty that now employs 2,500 people, says the essence



of the circus will always be amazing human skill. "Even if the setting were the Moon, it still would come down to what someone can do that is unbelievable. If someone could easily do three somersaults, then I'd find someone who could do thirty."

By the year 2030, says Burgess, bio-wonders might be performing under some orbiting big top. "I wouldn't be surprised if they tried to genetically engineer a four-armed juggler," he says. That could even lead to practical benefits. "Perhaps they could counteract the problem of calcium loss in space by creating people with rubbery limbs—a community of contortionists," he muses.

Burgess says that circus performers have always been masters of practical physics. "In 1768 the circus ring was born when trick riders used centrifugal force to maintain their balance while performing," he says. When the circus goes into space, it's only natural, then, that performers will take advantage of zero gravity. He speculates that live holograms of zero-g tricks could be transmitted back to audiences on Earth. "If the holograms could be adjusted to scale, the circus could be performed live in your living room with 12-inch performers," says Burgess, "or live at Madison Square Garden with 12-foot performers."

Ringling Brothers' near-term plans are thought to be more modest. Although the company won't confirm it, a full-scale model of the space shuttle has reportedly been commissioned for its traveling show. Beyond that, Burgess sees the opportunity to actually travel and perform in space as part of a natural evolution for circus performers. After all, he says, the Apollo space program was a kind of performance. "I never saw astronauts," says Burgess. "I saw men doing extraordinary things. To me, that's circus."

—Patrick Ryan

High on Champagne

Although they've been commissioned to hand-engrave champagne bottles for the likes of Madonna and Mick Jagger, New York artists Dave Sugar and Carol Iselin say their real passion is for the nation's space program. To prove it, they've spent up to 100 hours engraving commemorative bottles for space shuttle astronaut crews.

The connection between space and art began in 1983, when the pop-music duo Ashford and Simpson commissioned the artists to engrave a bottle of Dom Perignon for Ron McNair, who had taken the group's album "High Rise" along on his first shuttle mission. Three years later, McNair, Judy Resnik (a former schoolmate of Sugar's in Akron, Ohio) and the rest of the Challenger crew engraved their signatures on the etched bottle the night before their ill-fated launch.

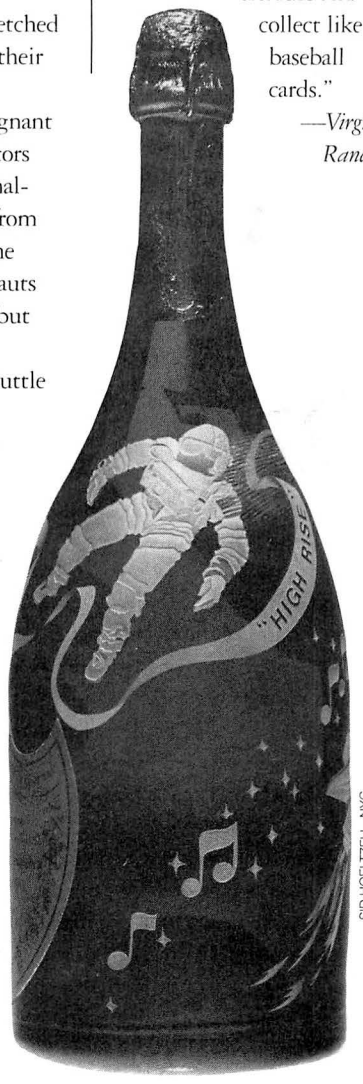
The memory is a poignant one. "Autograph collectors told us our keepsake Challenger bottle, 'Lessons from Space,' is worth a fortune because all seven astronauts signed it," says Carol, "but we'll never sell it."

Since then, several shuttle crews have drunk and signed commemorative bottles engraved for their missions. Mike Mullane took three of the artists' engraved crystal disks depicting an eagle's head along on his STS-36 flight last February, and the team has been asked to design the mission patch for an upcoming flight.

Although they're now creating more art pieces and fewer bottles, Sugar and Iselin still have stars in their eyes. Among their recent works are a crystal Mount Rushmore-like mural of the original Mercury 7 astronauts, which is displayed at a newly opened astronaut museum near Cape Canaveral, and a "Crystal Treaty" signed (with a diamond pen) by 47 astronauts and cosmonauts at an Earth Day celebration sponsored by the United Nations in April.

Needless to say, Dave and Carol would jump at the chance to be the first artists in space. In the meantime, besides invitations to launches and meetings with astronauts, they keep building their file of NASA memorabilia, which, says Dave, "I treasure and collect like baseball cards."

—Virginia Randall



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Spacefarers

Who's Up First?

When it comes to space tourism, money talks.

By Mikhail Chernyshev

It's hard to say who started it, but the ballyhoo arose shortly after the signing of a commercial agreement between the USSR Space Committee and the Japanese TBS broadcasting company in March 1989. Under that contract, one of the Japanese firm's employees will go into space in 1991 to spend a week with Soviet cosmonauts onboard the Mir space station, sharing the experience via TV reports.

But a cry soon went up among Soviet reporters, particularly those who had been covering space for a long time: "A Soviet journalist should fly first!" The journalists even banded together to found a "Space Commission," and held a competition for the best space-related story, with a spaceflight supposedly as the main prize. Officials remained indifferent to their complaints, however. The reason: The Japanese will pay good money for their flight.

When Yuri Bespalov, the Soviet Minister of Chemical Industry, offered to pay for the Soviet journalist's flight, it only set off a storm of public indignation: "What with the difficult situation in the chemical industry...the minister thinks he can afford space games," commented one writer in the press.

Champions for the Soviet journalist argued that a Soviet would enhance the country's international prestige. Opponents pointed out that a Soviet journalist had already flown in space long ago—Vitaly Sevastyanov, who before becoming the host of a TV program devoted to space exploration, made two Soyuz flights as a cosmonaut in the 1970s.

Still, 37 professional journalists had stepped forward by the beginning of this year for a medical checkup. Only six passed the tests. The lone woman among them, Svetlana Omelchenko of the newspaper *Vozdushny Transport*, was candid about her health "regimen."

"I can't set an example to others," said the Moscow native. "I've been violating it all my life. I've never gone in for sports or done my morning exercises. I don't have a daily timetable. I live on snacks, and I smoke."

Veteran space journalist Jaroslav Golovanov was against making health the main criterion for selection, anyway. "If we had to choose the most talented physicist to work in orbit, it would be strange to choose the one who has covered more kilometers on a bicycle simulator," he said. "We should send a mature journalist who has something to say to people."

As to whether the Soviet journalist would fly at all, however, media and space officials met again to discuss the question in mid-April. It was pointed out that the Japanese candidates had been working hard in Star City since October 1989, and that general space training takes about seven months, followed by training with a team. The two Japanese journalists will complete their training in November.

Meanwhile, the Soviet journalists have only recently been allowed to train. What with the packed schedule of Mir crew training until 1993, it's unlikely that a Soviet journalist will be squeezed in in the near future. For the time being, it looks as though Soviet journalists have lost to the Japanese press, with hard currency winning the game. □

Mikhail Chernyshev is a writer with the Novosti Press Agency.

Japanese journalists Toyohiro Akiyama (left) and Ryoko Kikuchi will beat their Soviet counterparts to the Big Story.

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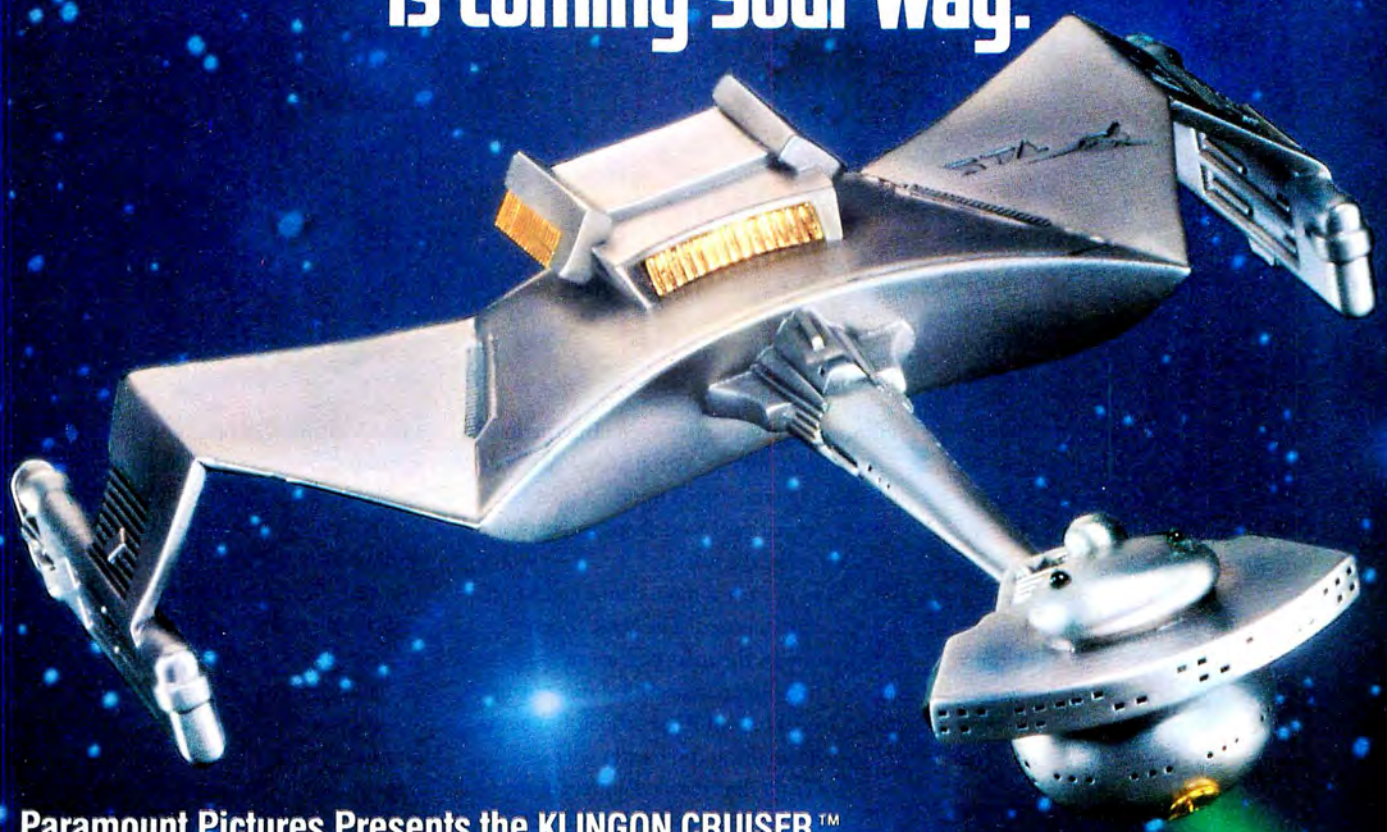

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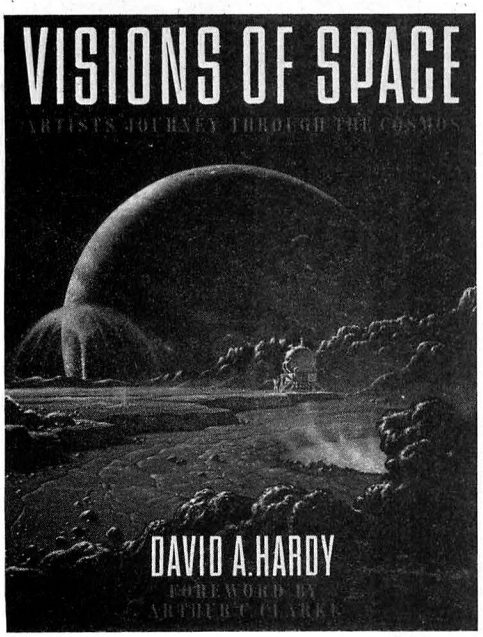
Review

Visions of Space
By David Hardy
Paper Tiger/Dragon's World
176 pages, $29.95

By Ron Miller

Space art is certainly familiar to the readers of this magazine, but few may know much about the genre's long and complex history or its ever-increasing scope. When I wrote the first book devoted to space art a dozen years ago, only 160 pages sufficed to cover the field, including its history and examples of virtually every space artist who until then had ever worked. Today, so many new artists have appeared in recent years that David Hardy has managed to fill an oversized volume almost exclusively with work by painters who have come into prominence since 1980.



Even though both books exhibit work by some 75 artists, there are only 10 or so names that overlap. The many artists who are now creating space art have even formed an organization—the International Association for the Astronomical Arts, or IAAA—whose several hundred members hold international workshops and exhibitions around the world.

Visions of Space is more than a collection of art reproductions. The book's opening section traces the roots of space art to at least three disparate historical movements: America's Hudson River school, England's Pre-Raphaelites and the early science-fiction illustrators. Painters of the Hudson River school—Albert Bierstadt, Thomas Moran and others—created highly romanticized works that brought the wonders of the American West to the awestruck citizens of the populated East. Both Bierstadt's and Moran's work played a major role in the creation of our first national parks: Yellowstone and Yosemite.

The Pre-Raphaelite landscape artists gave space art a tradition of depicting nature strictly and accurately, with as little personal "interpretation" as possible. The line of descent from the first science fiction illustrators is even more direct. In fact, at least two works by the French writer Jules Verne—*From the Earth to the Moon* and *Off on a Comet*—contain what may be the first examples of true astronomical art.

Hardy traces space art's lineage from Scriven Bolton and Lucien Rudaux (whose works, created mostly in the '20s and '30s, are so uncannily accurate that they still hold up today) to Chesley Bonestell and Ludek Pesek. Hardy makes it clear that most space art is not "mere" illustration, but a legitimate genre in its own right. Certainly Bonestell's space scenes rank with the best landscapes in American art.

The book is divided by subject: The various planets, stars and galaxies, fantasy and surrealism, "hardware" art and other topics each have their own sections. This format allows Hardy to present space art's amazingly diverse range of subjects and techniques. But it also lets the author slightly overindulge his own preferences, which include works depicting spacecraft.

The artists are all given biographies separate from the main text, and there is an excellent and thorough bibliography and index. The book's several hundred photos are reproduced from transparencies provided by the artists, and the quality is extremely high. British author Hardy is himself an experienced space artist who's been working in the field since the early '50s. He has illustrated numerous books, but he may be best known in this country for *The Challenge of Space*. Hardy is also the European vicepresident of the IAAA.

Perhaps the book's only faults are its failure to cover the NASA Fine Arts Program, which has been supporting coverage of the manned space program since the days of Mercury, and the lack of Soviet space art (which is not Hardy's fault: He was a victim of Soviet bureaucracy).

But the book's appeal crosses virtually every line of interest: art, art history, science fiction, astronomy and the history of astronautics. *Visions of Space* belongs in the library of everyone interested in the visual excitement of space exploration. □

Ron Miller is a space artist and author. His most recent book is Cycles Of Fire.

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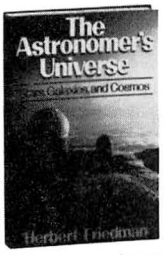

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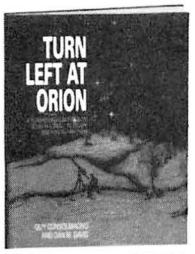

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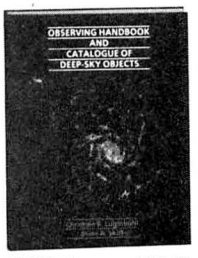

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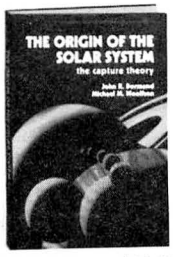

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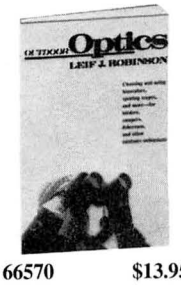

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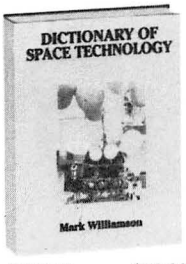

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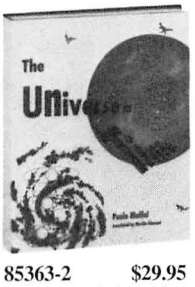

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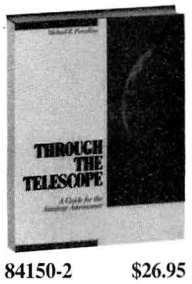

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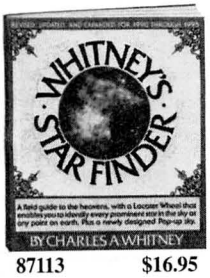

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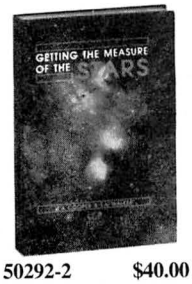

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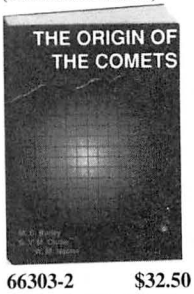

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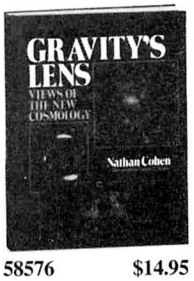

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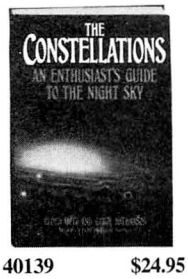

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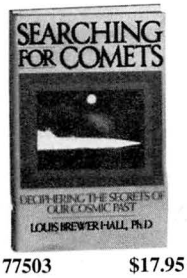

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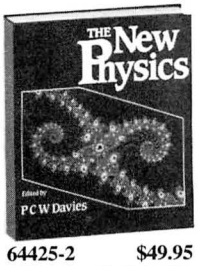

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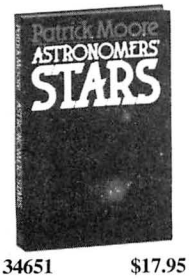

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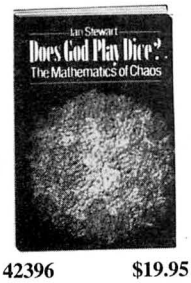

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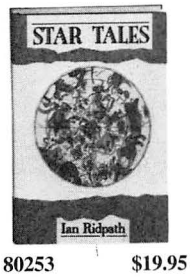

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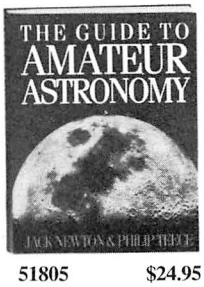

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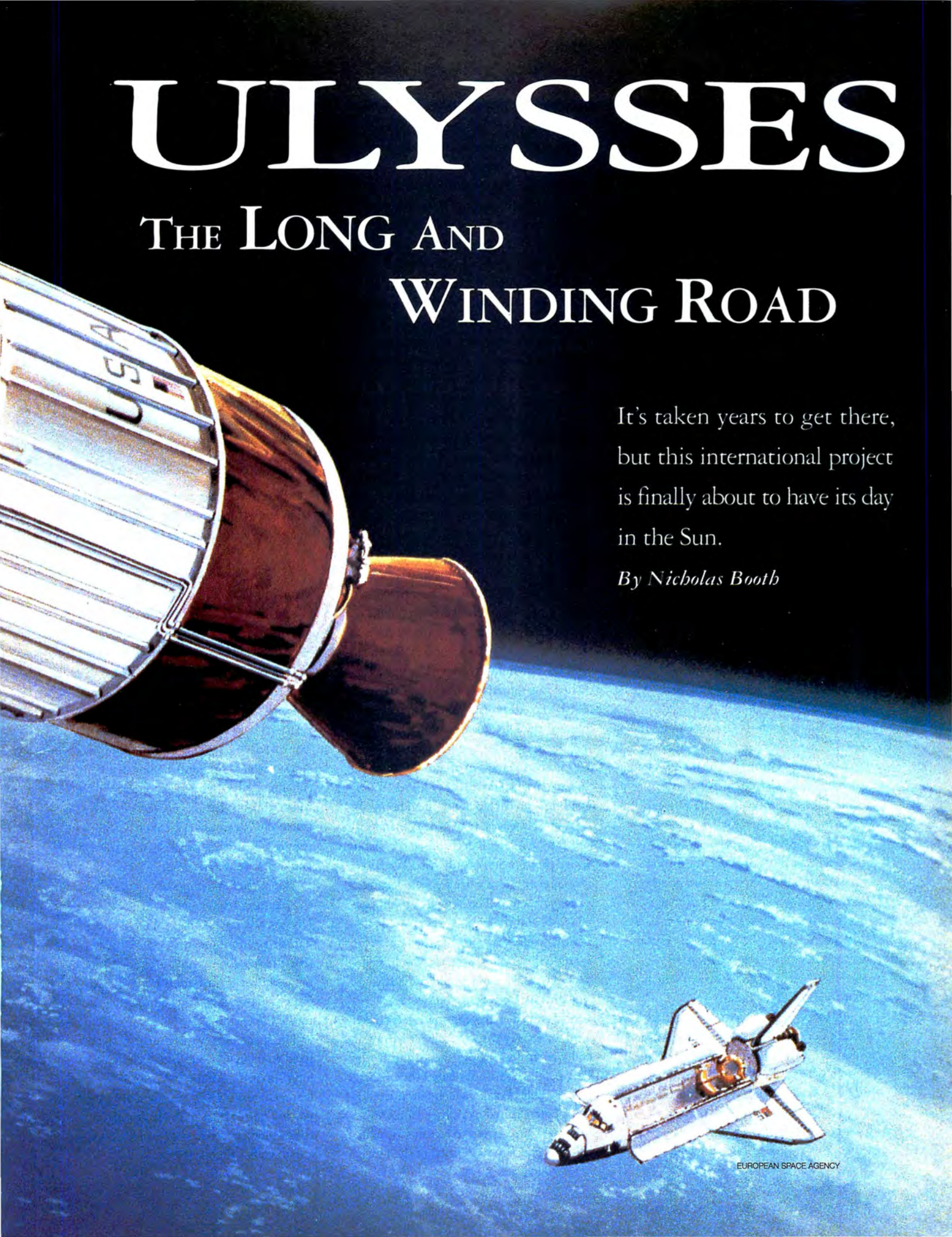
ULYSSES

THE LONG AND WINDING ROAD

It's taken years to get there, but this international project is finally about to have its day in the Sun.

By Nicholas Booth



EUROPEAN SPACE AGENCY

This October, the fastest manmade object ever sent into space will be sprung from the cargo bay of space shuttle Discovery to begin a unique, five-year journey of exploration. What the Ulysses probe seeks is not a new world but a new vantage point; its mission is to give scientists their first look at the polar regions of the Sun.

Like the hero for whom it's named, the European/American project has been beset by so many problems that its story takes on epic proportions: Cost overruns, international disputes and countless delays have given way in recent months to legal challenges by protestors who oppose the spacecraft's use of a nuclear-powered battery.

The fact that Ulysses exists at all is a triumph in the face of adversity.

Ask Derek Eaton, the man most people cite as the mission's motivating force, and the only one who has remained with the project since its inception. The British-born project manager for the European Space Agency (ESA) has spent more than 15 years of his career devoted to Ulysses. He bears the mien of someone who has learned the value and virtue of patience. "The main lesson I've learned," he says today, "is that there's no such thing as guarantees. Space is a risky business—you have to accept that."

Looking back on those years, Ulysses seems a case history in how *not* to organize an international project. The notion of an international "solar polar" mission had its beginnings in 1974, when the European Space Research Organization (ESA's forerunner) discussed the idea with NASA. The scientific rationale was straightforward enough. Despite the Sun's proximity, scientists are wholly ignorant of many aspects of our neighboring star because we have a limited view of it. Our observations of the Sun are limited to within 10 degrees of the "ecliptic" plane in which the planets orbit.

"It's like trying to study the weather if you could only make measurements near the equator," says Edward Smith, the Ulysses project scientist at NASA's Jet Propulsion Laboratory (JPL) in Pasadena.

Spacecraft have shown that the Sun's influence extends across the whole Solar System in the form of the solar wind, a plasma made up of superheated electrons, protons, heavier ions and nuclei emitted from the Sun's outer atmosphere. "The Sun's outer atmosphere is an extended region beyond the Sun, continually blowing out into the Solar System," says Smith.

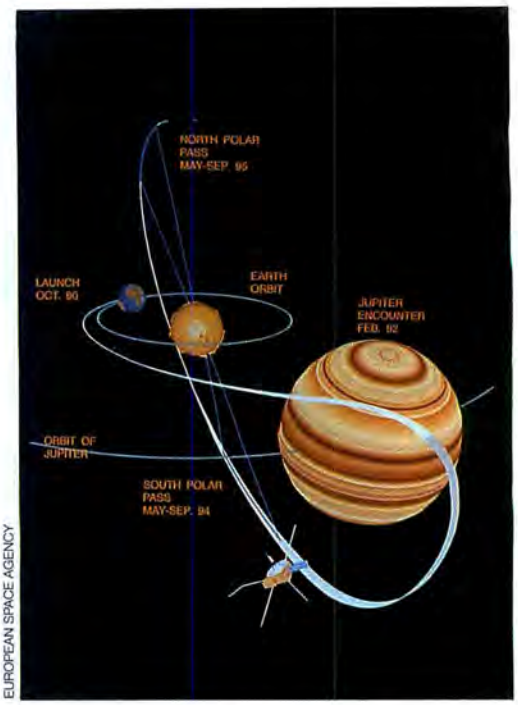
Even our view of this solar wind is complicated by our position. Because the wind is electrically charged, the Sun's extensive magnetic field causes the plasma to rotate with it. As a result, the solar wind is sprayed out like water from a garden sprinkler, trapped by the Sun's magnetic field lines into a spiral pattern.

To improve our view of these complicated dynamics, the International Solar Polar Mission (ISPM) was proposed. Plans called for two near-identical ISPM spacecraft to be launched in 1983. One, supplied by NASA, would pass over the Sun's north pole at the same time as a second ESA probe would round the south pole.

But cost overruns with the space shuttle and the knife-wielding propensity of David Stockman ensured that this happy state of collaboration soon was shattered. The way in which NASA pulled out of the deal still rankles some European project people, who tell apocryphal versions of the story in bars or under cover of darkness. Neither ESA nor NASA officials will be drawn into the fray, but what happened was something like this: Early in 1981, the Administrator of NASA telephoned the Director General of ESA to say, in effect: "The budget mark-up is in, and it's bad news, I'm afraid. We're going to have to cancel our half of ISPM. We're holding a press conference in an hour."

And that was it. One NASA manager reflects: "Unilateral decisions and collaborative projects don't really mix. We had absolutely no idea what we were letting ourselves in for." The launch date slipped to 1986, and the project was cut in half—NASA would now provide the launch for a single European spacecraft, would help with navigation, and would provide tracking with its Deep Space Network.

Still miffed, European managers scored a minor victory three years later by unilaterally renaming the project. A number of ESA people had always hated the NASA title of "Solar Polar," which Eaton would say is better suited to an ice cream. An informal competition to rename the craft led Professor Bruno Bertotti of the University of Pavia to propose "Ulysses."



EUROPEAN SPACE AGENCY

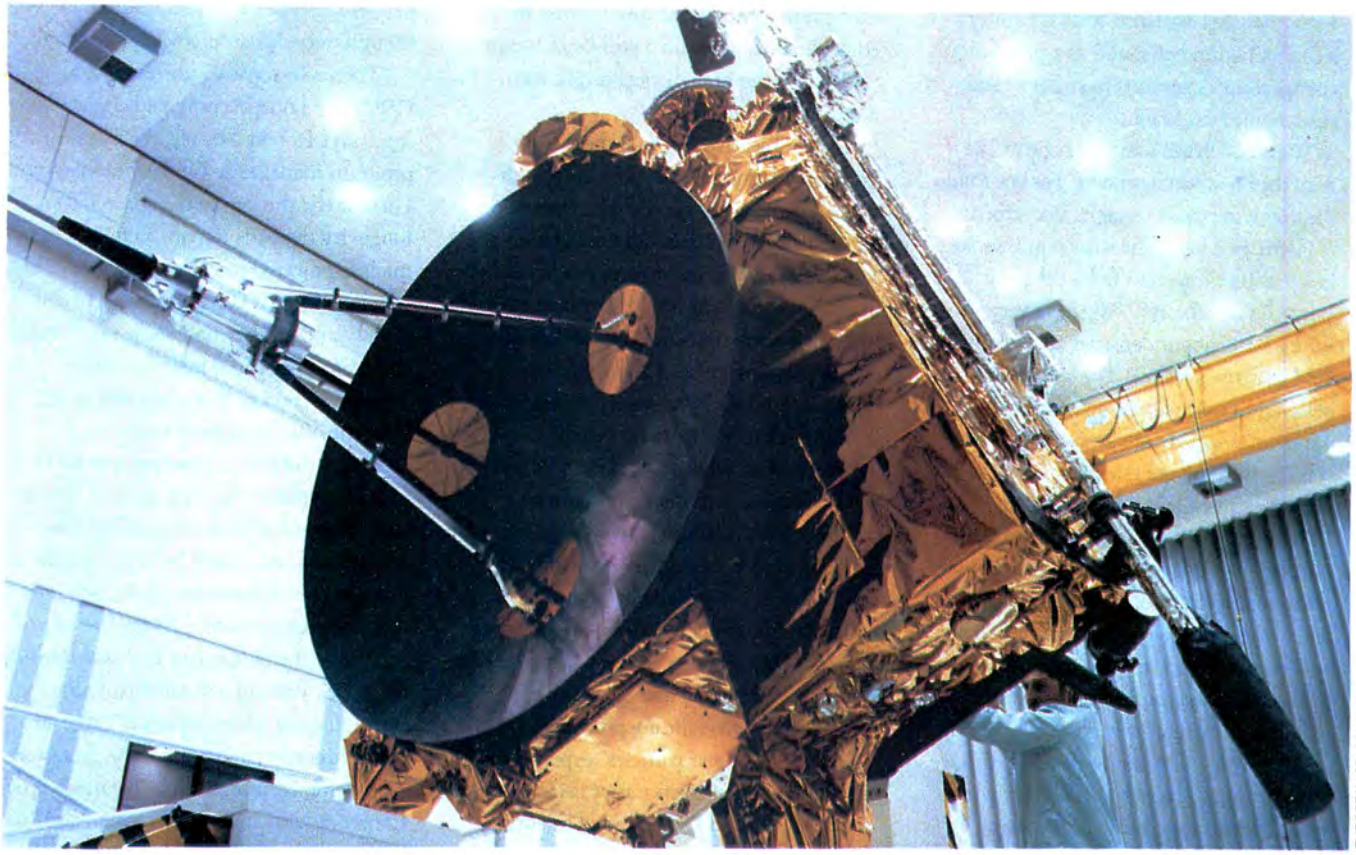
First stop, Jupiter: A gravitational assist from the giant planet will swing Ulysses out of the ecliptic plane in 1992.

"As the whole project had become a bit of an odyssey, it seemed apt," an ESA scientist says. The name was duly announced to the press in Europe before NASA could weigh in with its own candidate, and Ulysses it became.

Since that nadir in the early 1980s, relations between the two agencies have improved. "We realize that the European system works differently—not better, just different," says JPL project official Ed Massey. Derek Eaton, too, seems more tractable. "I've been critical of NASA in the past. But those criticisms are the sorts you'd reserve for any bureaucracy."

When the Challenger accident delayed the planned 1986 launch yet again, Ulysses was rescheduled for this October. Eaton's single-mindedness has ensured that the spacecraft will be ready despite its many journeys through Europe, out to Cape Canaveral, back to Europe and back to the Cape again.

The spacecraft carries nine experiments fixed to its main body and mounted on long "booms." All are the products of collaborative efforts. "Space scientists are getting better than industry at putting consortia together to get [experiments] on a spacecraft," Eaton reflects.

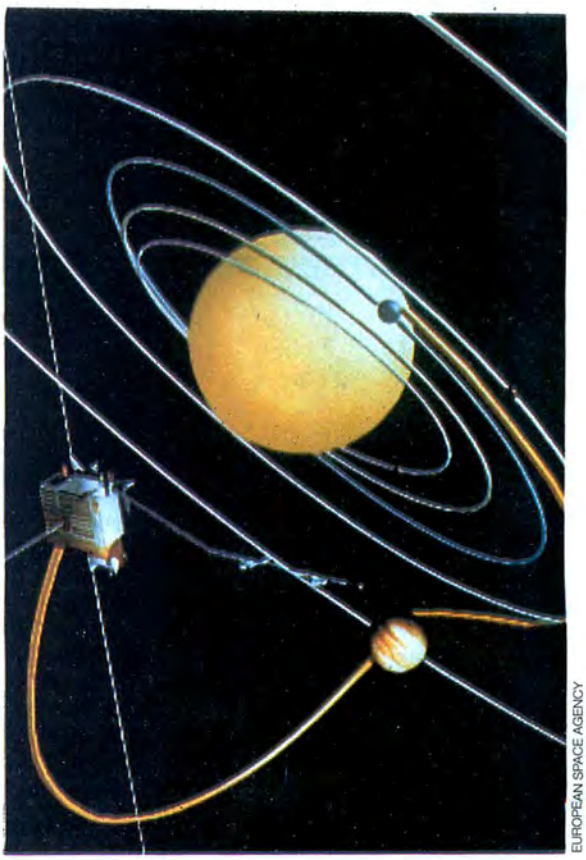


EUROPEAN SPACE AGENCY

Six hours after the shuttle reaches orbit, Ulysses will be released from Discovery's cargo bay to fire two separate solid-fueled boosters, one after the other. (The choice of upper stages has been an odyssey in itself, with no fewer than three changes to the original project plan. When a proposed Shuttle-Centaur upper stage was scrapped after the Challenger accident, the dual-booster scheme was devised for Ulysses.)

Once free of the shuttle, the spacecraft will speed outward to Jupiter so that it can use the planet's immense gravitational energy to pick up the velocity needed to head out of the ecliptic plane. Traveling at better than nine miles per second, Ulysses will reach Jupiter in only 16 months. The criticality of its trajectory cannot be overstressed: Its aim point at Jupiter is a moving target some 100 miles wide and nearly 500 million miles away. Hurtling over the planet's north pole, the spacecraft will be propelled downward to pass under the south pole of the Sun in May 1994. By the time it comes "half circle" over the Sun's north pole in May 1995, nearly five years will have elapsed since launch.

In this regard, NASA's ability is pre-eminent: JPL navigation engineers have perfected such games of cosmic billiards with the Voyagers and Pioneers.



EUROPEAN SPACE AGENCY

Data from instruments mounted to the spacecraft will be relayed back to Earth by a large-dish antenna (above). Right: the probe will pass under the Sun's south pole in mid-1994, then up and over the north pole a year later.

"To those guys, [the gravity assist] is not too difficult a task," says Derek Eaton. Ulysses will also broach Jupiter's lethal radiation belts, and as a precaution, the spacecraft's systems have been hardened against radiation.

What do Ulysses scientists hope to "see" from their new vantage point? For one thing, the solar wind could reveal its true structure.

"Perhaps a lot of the solar wind we see here has been diverted from the polar caps," Ed Smith says. "We have very limited data about densities and magnetic field structures there." The solar wind is believed to originate in holes in the Sun's upper atmosphere, or corona, which have been seen in images taken at x-ray and ultraviolet wavelengths from space.

"Ulysses will allow us to put something behind those images," says David Southwood of Imperial College. Holes at near-polar latitudes, seen as dark patches in x-ray and ultraviolet images, may be easier to observe away from the complicated magnetic regions closer to the equator.

Above the poles, some theorists believe that the Sun's magnetic field lines will act as funnels for cosmic rays coming from deep space, about which little is known. Because they get mixed in with the solar wind at the equator, it's difficult to determine the cosmic rays' origins.

Onboard instruments also will detect dust particles and their distribution in three dimensions, which will be of use in understanding how planets might form around other stars.

Other objectives include measuring Jupiter's magnetic field, detecting high-energy gamma ray bursts from elsewhere in the galaxy, and searching for gravitational waves. The latter were predicted by Einstein, and result from disturbances in the space-time continuum caused by the violent collapse of stars and other objects into black holes. By carefully monitoring Doppler shifts in the radio signals returned from Ulysses, the fastest object ever launched, scientists may gain an insight into gravitational waves.

In purely PR terms, Ulysses will be hamstrung by its lack of cameras or any other "imaging" instruments. Anyone who's witnessed a Voyager press conference has noted the general fidgeting and cumulative exodus of reporters during presentations on so-called "fields and particles" experiments.

"Fundamental science isn't necessarily sexy," says David Dale, head of scientific projects at ESA. Ironically, had the NASA ISPM craft been launched, it would have had a solar coronagraph from which exotic pictures would have been returned.

Beyond the official end of the mission in 1995, Ulysses will still return data—though nobody can predict for how long.

"There's [electrical] power beyond [1995] for housekeeping and engineering," says Robert Murray, the Ulysses program manager at NASA headquarters. Ultimately, the key to the spacecraft's longevity depends in part on how well its nuclear-powered radioisotope thermoelectric generator (RTG) performs. There is always a possibility that some instruments and some data could be returned on Ulysses' second pass of the south pole, after the official mission ends.

Long before that, however, the RTG will play another key role in the Ulysses story. Project officials are gearing themselves up for an assault by anti-nuclear groups who will protest the launch into space of approximately 25 pounds of plutonium—the radioactive fuel sealed inside the RTG. Fearing a shuttle explosion could disperse plutonium and cause an environmental catastrophe, the protestors plan demonstrations at the Kennedy Space Center at launch time. Litigation also "is still alive," according to Lanny Sinkin of the Christic Institute, one of several groups whose attempt to block NASA's

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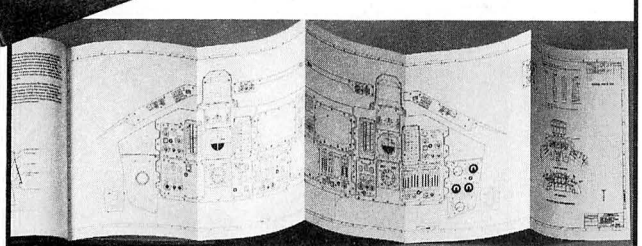

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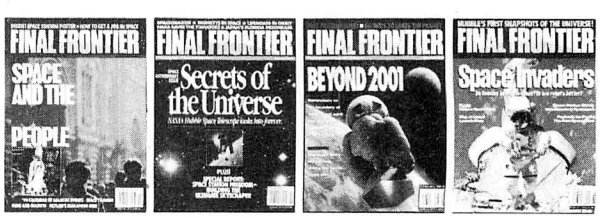

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Galileo launch was dismissed in U.S. district court last October.

Any discussion involving nuclear issues tends to be obfuscated by emotions and exaggeration, and this is no exception. One NASA scientist, when pressed, declares: "I can understand [the protestors'] concern. Our government hasn't exactly made a name for itself on the nuclear issue."

But in fact, NASA has extensively tested the protective casings for RTGs, assessing their integrity in all kinds of accident scenarios. The consensus among most informed reviewers is that the threat from the RTGs is negligibly small. And, grumbles an impatient Derek Eaton, "The analyses have cost as much as the spacecraft."

Ironically, Eaton won't be at the Cape in October to witness the launch of Discovery in person.

"I've always said that the role of the project manager is in operations control," he says. "The day before the launch I'll travel to the Jet Propulsion Laboratory. If there are any nasty decisions to be made, I want to make them with my JPL counterpart." □

Nicholas Booth writes about space for The Observer *and* The Guardian *newspapers in London. His seventh book,* Space: The Next 100 Years *will be published by Crown in October.*

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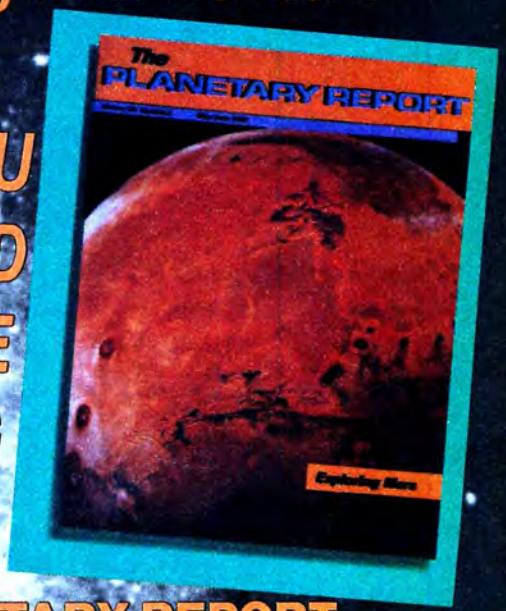

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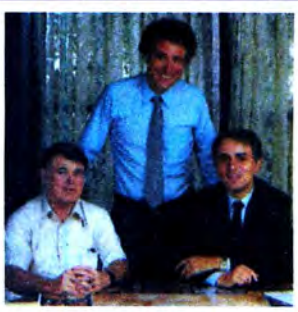

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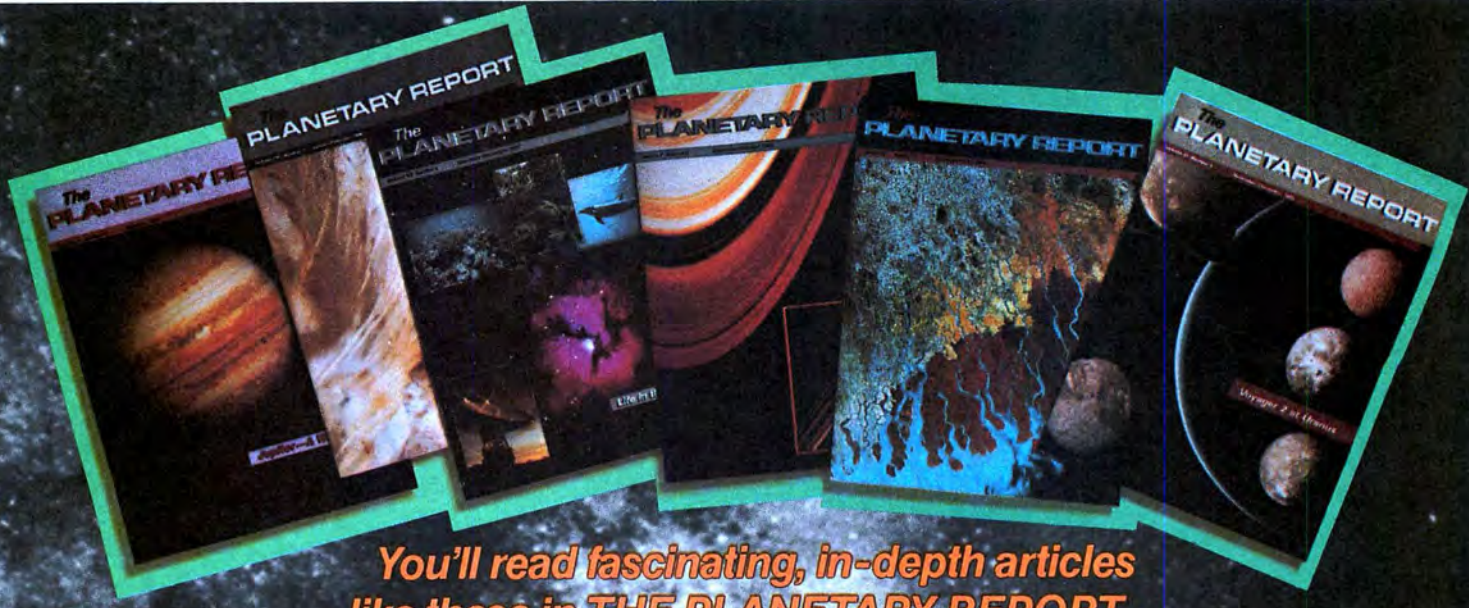

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New Worlds

International Plans for the Moon and Mars

A FINAL FRONTIER SPECIAL REPORT

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The Moon and Mars are natural and obvious destinations for 21st-century space explorers. Robots have visited both places already, and American astronauts walked on the lunar surface more than 20 years ago. Now a new international space scene is unfolding. Has the time finally arrived to begin a planet-wide push to extend human civilization to other worlds?

By Alan Ladwig and Terri Vogt Ramlose

Missions From Earth

Last March, President Bush announced that the United States would seek an "exploratory dialogue" with Europe, Canada, Japan, the Soviet Union and other nations to discuss international participation in his so-called Space Exploration Initiative (SEI), which aims to establish a lunar base and send humans on to Mars. The decision was based on a recommendation by the newly created National Space Council that cooperation was "feasible and could offer significant benefits to the United States."

The Soviets have long favored such a joint effort, and have been actively engaged in the hunt for Red Planet collaborators. But many American space experts believe there is no *technical* requirement to make this an international effort; the United States, they insist, is fully capable of going it alone to Mars.

If it were only technical know-how that was required, they might be right. But it's obvious that a 30-year quest to set up human outposts on other worlds will have political overtones as well.

Most Americans believe that the exploration of space should be a multinational undertaking. In a Market Opinion Research poll sponsored by Rockwell International last March, 77 percent of those surveyed "welcomed the notion of space missions that include the participation of both the U.S. and other nations." It's no secret that the Bush administration is as poll-conscious as they come, but it was probably a coincidence that the survey results were released only two weeks prior to the president's announcement of a dialogue on international space cooperation.

Good reasons have been offered as to why a lunar base or Mars expedition should be an international endeavor. Proponents say that cooperation would speed things up and make the missions more affordable. By opening the planning process to all interested nations, the best minds in the world would be brought together to design the most efficient and innovative missions. Needless duplication could be avoided, and perhaps most alluring, world tension could be reduced as humanity aims its rockets at the stars instead of at each other.

Cooperation also has its detractors, who claim there's no solid evidence that things would go cheaper or more quickly in a joint venture. National security and economic competitiveness issues make others nervous. And given the dynamics of political change in the world these days, *no* nation may want to tie its exploration program too closely to any other's.

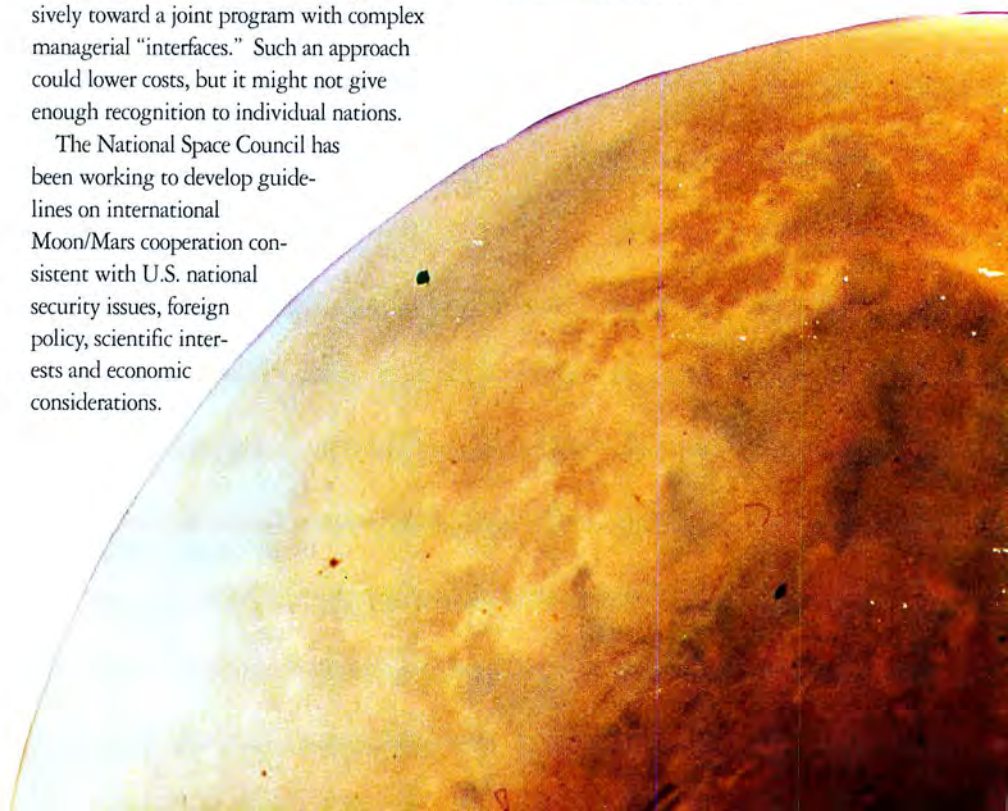
What form should cooperation take, if it happens? Would prospective partners go out on a few dates first, or rush down the aisle to get married? A slow start—with separate but coordinated programs—would minimize technical and management problems, but might not realize the same cost savings. At the other extreme, we could move aggressively toward a joint program with complex managerial "interfaces." Such an approach could lower costs, but it might not give enough recognition to individual nations.

The National Space Council has been working to develop guidelines on international Moon/Mars cooperation consistent with U.S. national security issues, foreign policy, scientific interests and economic considerations. Those who would like to see things happen quickly should relax. The Council intends to take a "sequential and orderly approach to decisions involving specific countries."

This fall, the first step in what's sure to be a long process will take place when a U.S. delegation sanctioned by the Space Council will begin "dialogue" sessions with representatives from other countries. The meetings are intended only to determine "conceptual possibilities" for cooperation, and will take place over the next year or two. Each participating nation will be weighing its own interests, and few potential partners will rush to sign up for a program that has "U.S. space leadership" as one of its announced goals.

Mission to Reality

At a White House "space summit" meeting in June, President Bush outlined his plans for the Moon and Mars to the leadership of the House and Senate. After the meeting, Senator Albert Gore of Tennessee quipped, "I think the president needs a mission to reality." In fact, before the United States can think about signing on international collaborators for



trips to other worlds, there's still a lot of convincing to do right here at home.

Is an ambitious Moon/Mars program too much for NASA to handle at this point? The agency already has its plate full with the space shuttle and new science missions, not to mention development of space station Freedom. In the middle of recent congressional debates over allocating new money to explore the Moon and Mars, NASA was suffering embarrassing problems with leaky shuttles and myopic space telescopes.

As of midsummer, the House had given the Space Exploration Initiative a resounding "no" vote, eliminating all funding for Moon/Mars-related work in its 1991 budget recommendation. Few observers thought that by the time Congress agreed on a final budget this fall, the president's program would fare much better. For at least another year, then, SEI appears to be on hold.

Add to these woes the poor U.S. track record as an international partner in space projects. Recent changes to the Freedom space station and NASA's backing out of an agreement to place an instrument on the Soviet Mars 94 spacecraft in June have not improved that reputation.

Meanwhile, Soviet space officials struggle with hardware problems on the orbiting Soyuz/Mir complex, while an angry Soviet public questions whether money spent keeping cosmonauts in orbit might not be better spent on bread.

The nations of the European Space Agency (ESA), already hard-pressed to support their commitments to the space station and Hermes space plane, are becoming more vocal about the need for stability on the part of the United States before they jump on the Moon/Mars bandwagon. As ESA's Washington representative, Ian Pryke, told aerospace officials in May, "Before we commit to SEI, we are going to need a warm fuzzy feeling about the stability of Freedom."

Japan's vision for a future in space is aggressive, but that wish list has yet to be approved. Japanese space engineers have their hands full trying to build the new, homegrown H-2 rocket. The degree of public support for space is an unknown as yet—today tuna fishermen have more political clout in Japan than do space advocates.

With all these challenges, some critics claim that we shouldn't be focusing on long-range visions. Others insist that as nations turn away from military adventures toward more peaceful pursuits, space exploration offers an outlet for advancing technology and scientific knowledge.

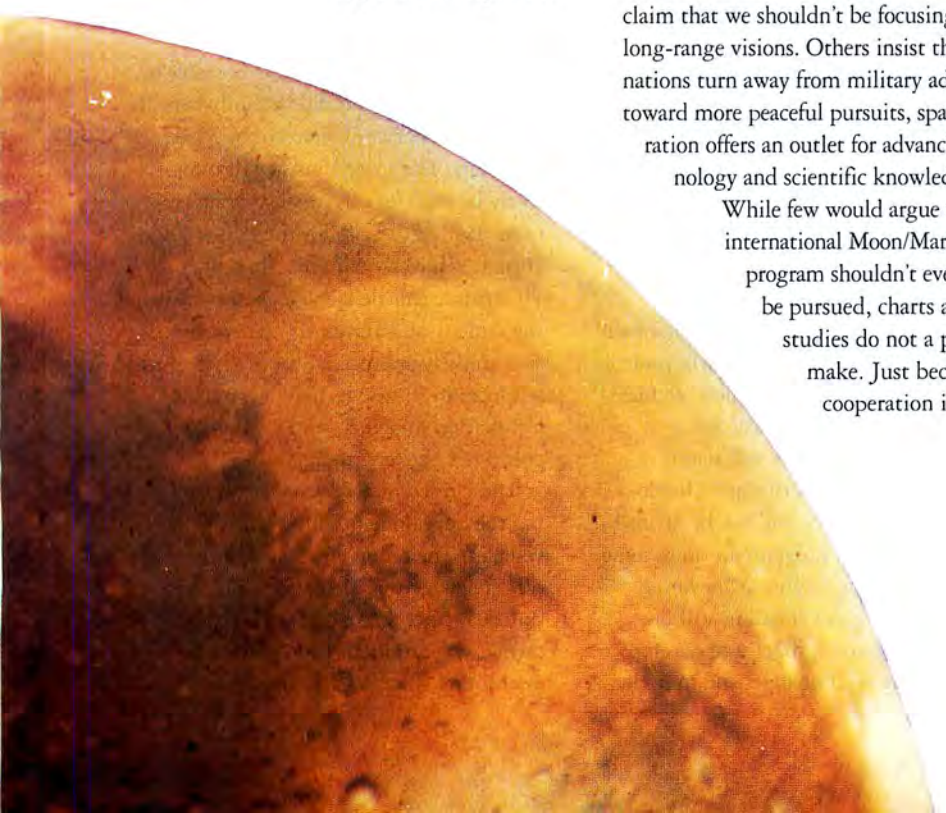
While few would argue that an international Moon/Mars program shouldn't eventually be pursued, charts and studies do not a program make. Just because cooperation is a great idea, there is no evidence that cooperation will happen overnight. The recent history of the space program—the U.S. program in particular—is full of false promises and overeager salespeople, and it would be very unfortunate if a house of cards were to tumble down in a room full of international partners.

But in fact, cooperation for Moon/Mars exploration has already begun. Canada, Japan and ESA are already collaborating with American space engineers on space station Freedom and the Mars Observer. Americans, Europeans and Japanese are working with the Soviet Union on the Mir space station and Mars 94 mission. Such cooperative projects cannot be underestimated as first steps on the road to the Moon and Mars.

Almost three decades ago, during a speech at the United Nations, President Kennedy proposed that our quest to the Moon might be an international effort. The politics of the time did not allow for the fulfillment of that dream. Adlai Stevenson, Kennedy's United Nations ambassador at the time, left us a message of hope: "Perhaps our children will sail together to Mars."

Perhaps we will.

In the meantime, *Final Frontier* has reviewed the various programs taking shape around the world related to Moon and Mars exploration. Who's planning what? What is each nation's strength and state of readiness, and what contribution might each make to an international program? This "tip sheet" undoubtedly will be filled out in more detail over the next few years, as the nations with aspirations in this bold new arena search for partners to help build the long highway to the planets.

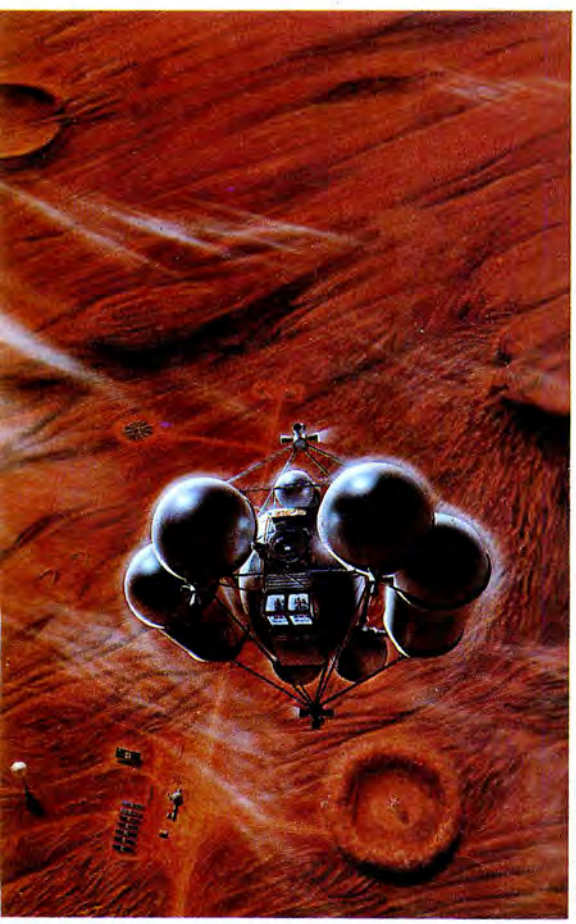


United States

It's important to understand what the Space Exploration Initiative is, and what it isn't. In an oft-quoted speech, delivered on the 20th anniversary of the Apollo 11 lunar landing, President Bush articulated a three-step strategy: first space station Freedom, followed by a return to the Moon ("this time to stay"), then finally a human mission to Mars. In May, Bush even set a deadline for planting the American flag on Mars: 2019.

The United States intends to lead this effort. But will it all happen? Not in recent memory has a space program elicited such strong opinion at such high levels of government. On one side of the controversy are the president and the National Space Council, backing the program with a strength that's the stuff of a space advocate's dreams. On the other side is the kind of congressional opposition that led the House, in budget negotiations over the summer, to cut its recommendation for SEI funding to zero. If the United States is to play a leadership role in human space exploration, the merging of these two wildly differing points of view is absolutely critical.

Consider also the issue of how such a program would be managed. NASA, the traditional agency for all civilian U.S. space programs, will be a strong player, but probably only one of several. At this point, the National Space Council, chaired by Vice President Quayle, is taking the lead in all matters associated with SEI, and the Council includes members from a number of different federal agencies. All will play key roles in SEI. What these roles will be remains to be seen.



NASA / PAT RAWLINGS

At the moment, SEI is not a program. It doesn't have a milestone chart associated with it, and it may not meet with the congressional approval required to make it fly. What SEI *is* today is a gleam in the president's eye that's shared by some of the nation's top political figures, scientists, aerospace engineers and space advocates. Many of these people are working with private company funds or even on their own time, hoping their ideas will find their way into the mission "architecture" that the National Space Council ultimately will select.

It is clear that the Space Exploration Initiative will not be defined as a national program for quite some time. In the meantime, however, America is not standing still.

A vigorous program to develop "pacing" technologies and to understand the human factors involved in long-term missions to the Moon and Mars already has begun. The Mars Observer mission, an important precursor to human exploration, is just two years away. NASA contractors such as Boeing, Martin Marietta, Rockwell, McDonnell Douglas and General Dynamics, to name a few, have established Moon/Mars planning offices for preliminary studies. Companies like Fluor Daniel and Bechtel, who have little previous space engineering experience, are teaming with traditional aerospace corporations to find a niche in SEI. And smaller groups, such as the Princeton-based Space Studies Institute, are developing innovative concepts for reaching the Moon independent of government efforts.

Launch Vehicles

Regardless of what shape the SEI ultimately assumes, human exploration of the Moon and Mars is certain to require vehicles with capabilities well beyond those of any existing in the U.S. fleet today. The massive amounts of cargo envisioned for vehicle assembly, equipment, facilities and fuel mandate a quantum leap in American launch operations.

The current and planned U.S. stable of expendable rockets could certainly launch precursor robotic missions to the Moon and Mars. The space shuttle will most likely be used for carrying astronauts to orbit. But a full-up Mars mission with current vehicles would require more than 20 separate shuttle launches at virtually the same time—obviously an expensive and unlikely approach. Even with planned advances in shuttle technology, human exploration missions would remain difficult if not entirely impractical.

The United States is currently examining the development of heavy-lift launch vehicles. The proposed "Shuttle-C" concept, which would swap out the space shuttle orbiter for an unmanned cargo carrier, was originally proposed for use in assembling space station Freedom,

although that plan is not currently in favor at NASA. If the Shuttle-C is developed, the next step up would be a larger vehicle scaled specifically for missions to Mars. NASA has had shuttle-derived vehicle concepts on the drawing board for several years, and if built, they would be good candidates for exploration missions.

Another U.S. venture in the area of heavy-lift vehicles is the Advanced Launch System, currently being studied by NASA and the Department of Defense as a means to drastically reduce the cost of launching cargo into space. Future versions of the Advanced Launch System could also support SEI, and studies have already been conducted to determine how this might be accomplished.

The National Aerospace Plane is another interesting possibility, at least for ferrying astronauts to and from Earth orbit. The goal of this joint NASA/DOD program is to demonstrate technologies for a single-stage-to-orbit vehicle that would take off and land like a conventional aircraft. An operational space plane, however, won't be available until early in the next decade.

Space Station

Space station Freedom is part and parcel of the president's exploration initiative, and a central element of many current designs for Moon/Mars missions. According to current plans, the basic international station will be completed in the late 1990s. But even today, Freedom's designers are conducting intensive studies of ways in which the station could evolve to accommodate future explorations: vehicle assembly, storage and servicing, and housing for crews in transit to and from the Moon and Mars (see "Heavens' Gate," July/August 1990).

Beyond its potential as a transportation node, Freedom will provide the United States and its partners with valuable experience in jointly managing a large technology project. The space station is by far the largest cooperative undertaking to date, and the political lessons learned over the next five to ten years are sure to be applied to any future international exploration program.

Freedom also will serve as a test-bed for life-science research and technology demonstrations, and will give space engineers fundamental experience in conducting the kinds of long-term space operations that would be necessary for the Moon and Mars.

Human Factors

At the heart of any attempt at human exploration of the Solar System is the issue of life-science research. Before explorers set up lunar camp or embark on three-year round trips to Mars, a wide range of health and safety issues will have to be addressed (see "The Human Factor," July/August 1990).

Life-science programs conducted onboard space station Freedom will provide a database on long-duration living in space. Research protocols are being developed to better understand the physical and psychological effects of working in microgravity, as well as to develop controlled ecological life-support systems that will produce food and recycle air, water and waste. A research program also has been proposed to study countermeasures to the negative physiological effects of zero gravity.

Other planned or proposed projects will bolster NASA's understanding of space life sciences. Lifesat, a proposed recoverable "biosatellite," will be flown in a variety of Earth orbits in the 1990s to examine the effects of space radiation on plants and animals. Other possible missions would monitor solar flares, a dangerous radiation hazard for travelers to the Moon and Mars.

NASA has planned an evolutionary program to address the critical areas of medical care, countermeasures, human factors, radiation protection and life

NASA / PAT RAWLINGS

Before designing Mars ascent vehicles (opposite page) or the next generation of lunar landers, a whole range of technological and political issues will first have to be addressed.

support in space. Programs developed for the shuttle and space station Freedom will form the basis for lunar missions. These in turn will lead to the next step, life support for Mars crews.

Robotic Precursors

A number of robotic missions to the Moon and Mars were in various stages of planning long before the president's Space Exploration Initiative emerged on the scene.

Proposed missions to the Moon will build on what we learned about our satellite in the 1960s. The Lunar Observer, which NASA proposes to launch in 1996, will provide global mapping and scientific data about the Moon's chemistry and gravity fields. Preliminary work on the project was begun this year, but it has not yet been approved as a funded mission.

Robotic missions to Mars, while also advancing science, will provide the information needed to land a piloted spacecraft safely on the Martian terrain. The Mars Observer, scheduled for launch in late 1992, will map the features and study the geochemistry and weather of the entire planet from Mars orbit. This mission was in development before the SEI was proposed. As a result of the Initiative's renewed interest in Mars, the data-receiving system of the Observer may be enhanced to take higher-resolution data.

After Mars Observer, the science community and NASA are developing a series of follow-on missions to return progressively more information about Mars.

A strong contender for a late 1990s mission is the Mars Global Network, a mission that would place a series of monitoring stations on the planet's surface at different locations. The stations would continuously relay information to Earth about seismic activity and Martian weather to further refine our understanding of the Red Planet.

Another possibility—one that has been discussed for quite some time—is a Mars Sample Return with a rover vehicle. Samples of Mars would be returned to Earth for study of soil composition, while the rover would collect data on desirable sites for human landings. Preliminary engineering work on rover vehicles is being conducted at NASA's Jet Propulsion Laboratory and other facilities.

And, for the first time in the history of the space program, the government is not alone in planning robotic missions to other worlds. Gerard O'Neill's Space Studies Institute in Princeton, New Jersey, is developing the first privately financed program for lunar exploration. The Institute plans to place its Lunar Prospector into a polar orbit around the Moon to search for water and other elements that would be necessary for a human base. The $5 million, 300-pound spacecraft is scheduled to be launched in 1992, and will carry a gamma ray spectrometer provided by NASA. A launch vehicle to place the probe in lunar orbit has yet to be selected.

Advanced Technologies

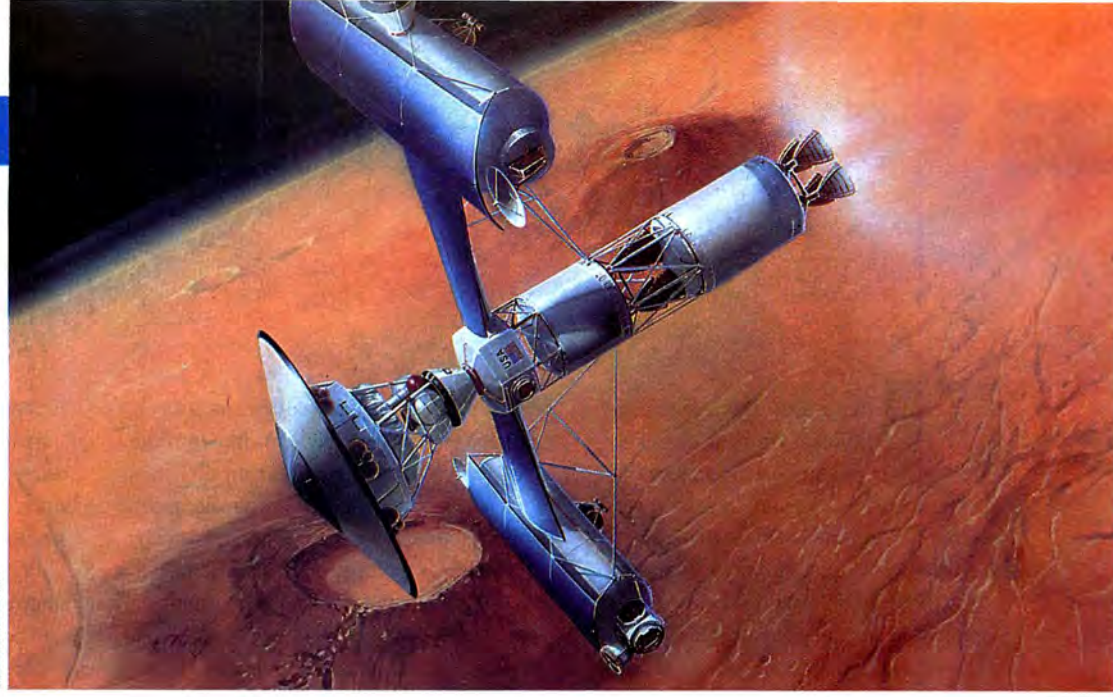
The need to improve America's technology base has been highlighted in every major study related to future Moon/Mars missions. Since it can take several years to conceive, fabricate, test and flight-qualify new technologies, it's important that this area receive high priority if new and innovative technologies are to contribute to mission planning.

Various NASA studies agree on the list of critical technologies that must be addressed for human exploration missions. Among those now getting priority attention are:

- Regenerative life-support systems that can recycle air, water and waste. Research and development are underway, and initial advances will be demonstrated on space station Freedom.
- The technique of aerobraking, which relies on the drag from a planet's atmosphere to decelerate a spacecraft, could lead to significant cost savings in designing planetary missions. To demonstrate the technique, NASA will fly the Aeroassist Flight Experiment on a mid-1990s shuttle flight.
- To provide the tremendous amount of electric power that will be necessary for bases on the Moon or Mars, surface nuclear-power systems are being investigated. The SP-100 program, a joint effort by NASA and the Departments of Defense and Energy, aims to validate the technology for a space reactor power system.
- The mining, processing and use of local resources on the Moon and Mars has been identified as another area where substantial savings can be realized. Researchers believe that lunar soil can provide material for construction as well as produce liquid oxygen for life support and fuels. While studies on the many uses of lunar and Mars soil abound, little has been done in the area of actual technology development.
- A growing number of researchers believe that many life-science issues and other problems associated with long-duration missions might be alleviated by using faster, more efficient rockets driven by nuclear propulsion. Development of nuclear thermal rockets and nuclear electric propulsion would cut down the travel time for missions to Mars considerably. In fact, the decision whether to develop nuclear propulsion is one of the most critical ones facing the Moon/Mars program.

For the past three years, NASA has attempted to advance its technology base in these and other areas through a program known as Project Pathfinder. Each year, however, the budget for this program has been slashed.

Repackaged for the 1991 budget as the Exploration Technology Program, NASA is again attempting to bring new technology capabilities into its mission planning. Budget-watchers believe this program will serve as a barometer for tracking the health of SEI as a whole. If funds can't be



MARTIN MARIETTA

Artist's concept of a spinning Mars ship: Will America follow through to make this a reality?

obtained for a modest beginning in technologies that would provide new and innovative approaches, the overall Initiative will suffer.

Mission Studies

Since the 1950s, many different scenarios for Moon bases and expeditions to Mars have been proposed. Mars missions have been designed (on paper) that would take as little as 14 months—or as long as several years—for a round trip using conventional propulsion. Nuclear rockets could allow even shorter trip times.

Specific mission architectures for the Space Exploration Initiative—the how, what and when of real engineering—will develop and probably change many times over the next two years. The SEI, after all, is little more than a year old. At the time of the president's speech, NASA was not the only agency interested in playing a part, and the National Space Council was put in charge of determining what was necessary for the "next round of exploration." Accordingly, several agencies, including NASA and the research labs of the Department of Energy, prepared to assist in collecting information for the president.

Out of these efforts came NASA's "Human Exploration Initiative" and the Lawrence Livermore National Laboratory's "Great Exploration" approach. The latter was offered as a radical alternative to current NASA thinking. Livermore planners, led by Lowell Wood, offered a Mars mission concept that relied on inflatable space stations and "quick and dirty" engineering.

But neither approach showed the sort of innovation the Space Council was apparently looking for. These efforts did, however, stimulate widespread interest in developing a plan for SEI that was fast, efficient and moderately inexpensive.

With the results of its so-called "90-Day Study" as a base, NASA is fine-tuning various mission scenarios to place before the Council. In the meantime, work on Livermore's Great Exploration program has been delayed until Congress approves funding to continue the research.

Additional mission ideas are expected to be realized from NASA's "Outreach" program (See box).

Reaching Out

When NASA released its *Report of the 90-Day Study on Human Exploration of the Moon and Mars* in November 1989, critics complained that it lacked imagination. The National Space Council responded by asking NASA to lead a nationwide search for new "space exploration alternatives" that might help fulfill the president's goals.

In casting a wide net for new thinking, NASA established an "Outreach" program to solicit innovative approaches to mission and systems concepts and advanced technologies that could affect cost, schedules and performance.

First, NASA administrator Richard Truly sent letters to individuals, universities, societies and corporations inviting their ideas. Truly vowed that "no stone will be left unturned" in pursuit of new ideas. A toll-free telephone number was even established so that individuals could order application materials and submit them by an August 16 deadline, after which the responses were to be analyzed and evaluated by The Rand Corporation.

A similar process was established for employees of the federal government. NASA employees sent their ideas through the agency's Office of Aeronautics, Exploration and Technology. With peace breaking out around the planet, scientists and engineers from the Department of Defense also were invited to submit ideas with new applications for their lasers, sensors and weapons technology. Employees from other government agencies and national laboratories directed their proposals through the Department of Energy.

The third phase of the Outreach Program was managed by the independent American Institute of Aeronautics and Astronautics (AIAA). Beginning last April, Institute members and other aerospace professionals began submitting proposals for review and evaluation by an AIAA technical committee. Those concepts judged worthy of further consideration are to be presented at an AIAA/NASA Conference on Innovative Technologies for the Exploration of Space in September.

Finally, the best and brightest of these ideas will be delivered to a NASA-established "Synthesis Group" led by Apollo astronaut Thomas Stafford. This group will look for the innovative ideas which, the National Space Council hopes, will advance our thinking about SEI beyond a "business-as-usual" approach.

Soviet Union

In the early days of President Mikhail Gorbachev's new policy of openness, Soviet space officials began making regular appearances on the conference circuit to outline their plans for missions to Mars. In contrast to the perceived floundering of America's long-range planning efforts, the Soviet program was held up as an example of the vision that America lacked. A few years into Glasnost, however, the long-term vision may still be there, but the Soviet "Mars program" turns out to be not all that definite.

It wasn't long ago that Gorbachev proclaimed "we do not intend to slacken our efforts and lose our vanguard position in the conquest of space." The goal to send Russians to Mars was formally announced by the Soviet president on the occasion of the launching of the Phobos 1 and 2 spacecraft in 1988. But in a time of restructuring and open debate over government spending by both the public and the press, the Soviet space program is under new scrutiny. Gorbachev's rival, Boris Yeltsin, has proposed delaying space projects from five to seven years, out of financial necessity.

In 1990, it is difficult to determine just who is in charge of the Soviet space effort and what constitutes the official long-range plan. There appears to be considerable jockeying for control of program planning and implementation. Responsibilities for space activities are divided among a handful of agencies, each with different agendas. The Space Research Institute (IKI), an arm of the Soviet Academy of Science, has primary responsibility for general space research, astronomy, space physics and atmospheric science. Once led by the charismatic scientist Roald Sagdeev, the influence of IKI has declined somewhat under the current director, Albert Galeev.

Among those gaining visibility as a spokesman for the Soviet space program is Valery Barsukov, director of the Vernadsky Institute of Geochemistry and Analytical Chemistry and head of the Soviet delegation for U.S./USSR bilateral activities on Solar System exploration. The Vernadsky Institute also reports to the Soviet Academy of Science. Whereas Sagdeev was a major promoter of international cooperation, Barsukov reportedly is more inclined toward a strong national program for Solar System exploration.

Glavkosmos, an agency under the Ministry of General Machine Building, has emerged as a major player in the determination of space policy. Created in 1985, the agency promotes commercial launch activities, manages the national space research and development program and manages Soviet engineering centers. Soviet cosmonauts remain under the direction of the Ministry of Defense.

Western space policy experts believe that Soviet space officials are at a crossroads. Will they continue with an active program of exploration, encourage commercialization and become more involved in international space projects? Or will they bend to internal pressures, slacken their efforts and lose their vanguard position? The next few years should determine the country's role in any future exploration of the Moon and Mars.

Launch Vehicles

The most obvious and oft-mentioned Soviet contribution to a cooperative Moon/Mars program would be the Energia heavy-lift launch vehicle. Any plan for sending humans into the Solar System will require the launching of many tons of equipment and material into Earth orbit first. And no near-term U.S., European or Japanese program can match the capabilities of Energia.

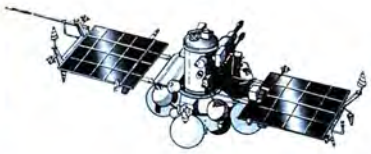
With an advertised capacity to launch 220,000 pounds into low Earth orbit (70,000 pounds to the Moon and 60,000 pounds to Mars), the vehicle should be able to handle the launch requirements for exploration missions. In the May/June 1990 *Final Frontier*, Yuri Semenov, General Designer of the Energia Research and Production Association, proposed that Energia be used for America's plans to return to the Moon. According to Semenov, the Soviets could "provide an Energia rocket, a booster for the delivery of cargo and crew from near Earth to a near lunar orbit," and other elements necessary to establish a lunar base.

Prior to this year's Bush-Gorbachev summit meeting, Planetary Society president Carl Sagan and Soviet scientist Roald Sagdeev recommended that discussions on Energia be added to the agenda. Sagdeev reasoned that since the Soviet program was in recession, and since Energia was being underused, it made sense to rely on it for the Space Exploration Initiative's heavy-lift requirements. There were no reports, however, that President Gorbachev discussed the matter in a meeting with Vice President Quayle at the time of the summit.

As a first step toward such a joint venture, it has been proposed that Energia haul tanks of water into orbit for eventual processing into fuel for lunar and Mars space vehicles. Sagan argues that, because Energia doesn't have an extensive track record, lifting water into orbit would be a safe and inexpensive means to test the vehicle. And since water is not exactly a strategic payload, issues of technology transfer wouldn't come into play.

Critics who don't like the idea of using a Soviet heavy-lift vehicle point out that technology transfer and national security issues would eventually crop up in an expanded Moon/Mars program. Proponents counter that Energia doesn't have to be a substitute for an American heavy-lift vehicle. It could just be an interim step until the U.S. version is ready. And to allay fears about sending U.S. payloads to Soviet processing facilities, perhaps the Energia vehicles could simply be leased for launch from American sites.

For all its potential capability, it should be remembered that Energia has only flown twice. The first test launch failed to deliver its payload into low Earth orbit, while the second launch successfully carried the Soviet shuttle Buran into orbit. Plans are to build one Energia per year, but that rate could probably increase with demand.



THE SOVIET YEAR IN SPACE, TELEDYNE BROWN

Space Station

While the benefits from NASA's international space station Freedom won't be realized until later this decade, the Soviets have been gaining experience with their space station, Mir, for several years.

The capabilities of Mir, with its Kvant, Kvant 2 and Kristall "add-on" modules, have extended the already considerable lead the Soviets had in long-duration living and working in space. This experience should contribute significantly to Moon/Mars mission development.

A second-generation Mir complex is currently being planned for occupancy in or around 1997. One of the long-range objectives of Mir 2 reportedly will be to serve as a spaceport for a lunar transportation system, sometime after the turn of the century.

Robotic Precursors

The Soviet track record in sending robotic probes to Mars leaves much room for improvement. The highly promoted missions of Phobos 1 and 2, launched in 1988, had been expected to vault the Soviets into a leadership position in the exploration of Mars and its moon, Phobos. But communication with the Phobos 1 spacecraft was lost shortly after launch. And, while Phobos 2 did succeed in sending back photographic and infrared data on Mars and Phobos, it also experienced communication problems, and contact with the spacecraft was lost before the most important mission objectives were completed.

Soviet scientists have outlined a three-stage approach for Martian exploration. The only currently approved mission is scheduled for launch in October 1994. Designed to study Martian surface features and atmospheric conditions, the objectives of Mars 94 are still under review. Some Western experts have even reported that the complete mission is not yet fully funded, and that the Soviet military is trying to wrestle funds from Mars 94 for other pursuits.

Currently, the mission consists of two spacecraft, each with an orbiter, science "stations" to be placed on the surface, a balloon experiment designed by the French space agency (including instruments contributed by the U.S. Planetary Society) and surface penetrators carrying Japanese-supplied cameras.

Data from the mission are to be relayed to Earth with the assistance of NASA's Mars Observer spacecraft, which is scheduled to arrive in Mars orbit in 1993. Plans for additional U.S. participation to map the planet's chemical composition with a Visual Infrared Mapping Spectrometer (VIMS) instrument were derailed in June due to budget problems at NASA—chalking up yet another demerit for American reliability as a partner in space projects.

Speculation as to what exactly constitutes the Mars 94 mission was further complicated by the comments of a Soviet scientist this past June. At the fourth Case for Mars conference in Boulder, Soviet scientist Lev Mukhin of IKI announced that a small surface rover might yet be added to the mission.

Beyond Mars 94, Soviet plans for missions related to the Moon and Mars are less certain. A plan to launch a dedicated Mars rover mission in 1998 has been proposed, followed by a Mars rover sample return mission in 2002. Representatives of the Planetary Society have reported that the Soviets also are conducting studies for a Phobos sample return mission in 1996 or 1998.

The Vernadsky Institute's Barsukov is said to favor a resumption of lunar exploration, which the Soviet Union abandoned in the early 1970s. He has proposed a Luna 92 polar orbiter mission that would rely on an improved version of the Phobos vehicle. The objective would be to compile photographic mapping, chemical composition and radiation data for the lunar environment. A 1996 mission to return surface samples from the far side of the Moon would follow. These missions would pave the way for the placement of an unmanned lunar laboratory in the year 2000.

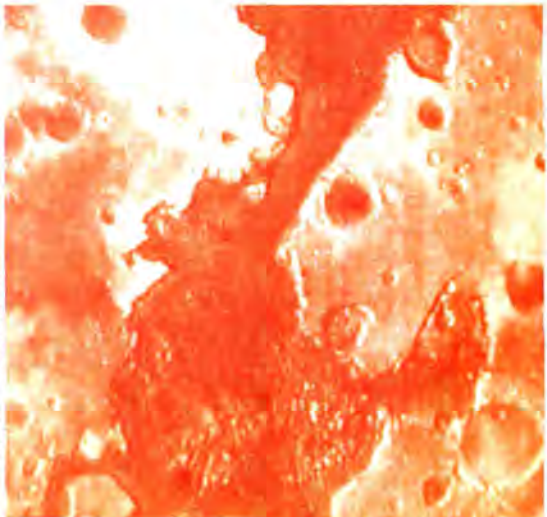
Human Factors

The Soviets have by far the most experience of any nation with long-duration living in space. Current scenarios for three-year round trips to Mars require in-depth understanding of a wide range of medical and psychological concerns. By the time the United States and its international partners are able to gain comparable data from astronauts on space station Freedom, the Soviets will have been living on Mir, and possibly on Mir 2, for 10 years.

Current U.S./Soviet cooperative agreements include a joint working group on space life-science research. Under the agreement, the countries are working to exchange and share space biology data.

Earlier this year, in the same press conference where Sagan and Sagdeev recommended the use of Energia, they proposed that Mir be used for joint research related to life-science concerns such as radiation, the effects of solar flares, artificial gravity and in-space construction. Mir cosmonauts already are experimenting with closed-loop life-support systems, including the recycling of wash water, moisture and urine. Plans are also underway to fly American-designed life-science experiments to be conducted by cosmonauts on Mir.

Room for improvement: Phobos 2 views Mars in 1989. Top: The proposed Luna probe would orbit the Moon in 1992.



SPACE COMMERCE CORPORATION

Advanced Technologies

Information on advanced Soviet space technologies applicable to the Moon and Mars is sketchy. The primary area where the Soviets enjoy a slight lead over their American counterparts is in space-based nuclear power. The Soviet RORSAT has shown the country's capabilities in this field.

Soviet research efforts on robotic rovers and planetary sample acquisition are believed to be on par with NASA's. According to Brown University space scientist James Head, the robotic drilling technology demonstrated on past Soviet Venus missions is "simple, but elegant."

At a recent press conference sponsored by the Planetary Society, Soviet engineers displayed photographs of a prototype Mars rover that appeared to be similar to a design being pursued by NASA. The Soviets also plan to build on their experience from the Lunokhod Rovers, which operated on the Moon and returned samples of lunar soil to Earth in the early 1970s.

Soviet efforts in space suit development and advanced nuclear propulsion are also comparable to the work going on in other countries. At a Soviet Space Engineering seminar held this summer at the University of Alabama in Huntsville, Yuri Zhakarov of the Moscow Aviation Institute outlined research plans related to electric propulsion as an alternative to nuclear propulsion.

Mission Studies

The current U.S./Soviet cooperative agreement calls for discussions on joint robotic exploration of the Moon and Mars, but makes no mention of human missions. The agreement does, however, allow for the exchange of studies. And while the results of Soviet studies on human missions have not yet been made available for review, missions to Mars are certainly on the drawing board.

Soviet space officials have talked openly of "manned" missions to Mars by 2010. Crews of anywhere from 4 to 12 men are being studied (with no indication that women are being considered for the trip). Soviet researchers appearing at international space conferences have mentioned plans for a Mars spacecraft to be assembled in low Earth orbit. This scenario would rely on upwards of five Energia cargo launches. The propulsion system most often mentioned for the Mars spacecraft is electric propulsion.

As Europe enters a new era of unification and cooperation, will increased activity in space follow? European scientists have shown interest in robotic exploration of the Solar System, but planting a flag on the Moon or Mars may not hold the same allure for Europeans as it does for Americans or Soviets. Which flag would it be?

The European Space Agency (ESA) already acts as a kind of "common market" for space activities. Fourteen nations (Belgium, Denmark, France, Austria, Italy, the Netherlands, Ireland, Spain, Sweden, Switzerland, the United Kingdom, the Federal Republic of Germany, Norway and Finland) belong to the consortium, which shares out the costs and benefits of programs as diverse as the Ariane launcher and the Ulysses mission to explore the Sun. Although most space programs undertaken by these nations are under the umbrella of ESA management, individual member states also pursue their own national space programs.

Europe is a prime candidate for participation in any 21st-century program to venture on to the Moon and Mars, if for no other reason than the strength of its economy, which will become even more formidable when the European nations join economic forces in 1992.

NASA and ESA have enjoyed a productive—if sometimes rocky—history of joint ventures. The very idea of cooperating with other nations on space projects is an integral part of ESA's philosophy. Until recently, however, Europe's involvement in space has largely taken the form of collaboration on U.S. and Soviet projects, including a wide array of Earth observation, space physics, and planetary missions.

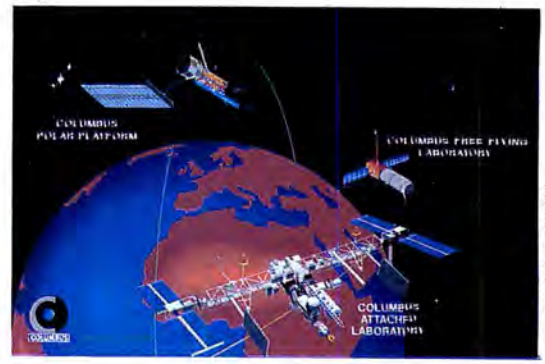
During the past decade, ESA has enjoyed noteworthy accomplishments of its own, such as the 1986 Giotto mission to Halley's Comet. Europe also has become an ever-stronger partner in increasingly larger programs, a trend that appears to be an important element of ESA's strategy.

Responding to the new spirit of Soviet openness, the agency signed last spring a new 10-year agreement with the Soviet Union covering space exploration. Activities covered in the agreement include Earth observations, life sciences and Solar System exploration.

With the growth of European economic power along with increased pride in technical achievements, it is unlikely that ESA's relationship with the United States will remain "business as usual." Staying a junior partner in American projects offers little appeal. Additionally, ESA's space interests are increasingly in the direction of advancing scientific knowledge. Numerous European scientists have become more vocal about the dubious virtues of space spectaculars as means to advance research goals.

Launch Vehicles

ESA has made a steady commitment to the development of an autonomous launch capability with its Ariane family of vehicles. Although the Ariane program has been fraught with technological setbacks, it is clear that ESA intends both to develop and sell its launch capability. With an already overcommitted U.S. shuttle, the Ariane fleet might be considered for selected precursor robotic missions conducted jointly by Amer-



EUROPEAN SPACE AGENCY

European Space Agency

icans and Europeans.

Another European contribution to long-range human exploration would be the Hermes spaceplane, a mini-shuttle being developed specifically for transport to and from space station Freedom. If Hermes proves successful, it may be used to ferry Moon or Mars crews to Freedom. The first unmanned demonstration of Hermes is scheduled to occur in 1998, with a piloted flight in 1999. Initially the spacecraft will land at the ESA space center in French Guiana, but a European landing site is also being considered.

Space Station

In a fundamental way, ESA is already involved in President Bush's Space Exploration Initiative through its participation in space station Freedom, the first step on the road to the Moon and Mars. Europe's contribution to Freedom—the Columbus research module—will give ESA experience in large cooperative ventures with the United States. That could either be good news or bad news for those rooting for international cooperation, however. The space station has been fraught with budgetary and other problems, and the final outcome of the Freedom project may well determine ESA's attitude toward participating in future complex exploration missions with Americans.

In any case, ESA's current partnership in building Freedom will provide valuable experience with international astronaut crews in space, something that may stand European astronauts in good stead as potential crew members for lunar or Mars missions. If Freedom evolves into a spaceport for reaching out into the Solar System, ESA may extend its contribution to participate in that evolution.

Currently, however, ESA shows signs of losing patience with America's wavering commitment to the project. And that dissatisfaction could lead to a more autonomous European space program. At an international meeting this summer, ESA's Mauro Novara announced that the agency is investigating preliminary ideas for an independent space station. Early plans call for an ESA-developed station facility with modules for research and habitation, plus an escape vehicle. The Hermes spaceplane would deliver three crew members to the station for four- to six-month stays.

Robotic Precursors

ESA's most likely contribution to any near-term plans for exploring the Solar System will be in preparing the robotic missions that will precede human explorers. European experience in spacecraft instrument design and development points could be particularly valuable for precursor Mars missions.

Before the U.S. Space Exploration Initiative was even proposed, ESA conducted a study to examine possible participation in an evolving international Mars exploration program. In a 1989 document titled "Mission to Mars: Report of the Mars Exploration Study Team," the agency earmarked the proposed U.S. Mars Rover/Sample Return mission as a potential cooperative venture to augment its long-term space program. In addition, the study team called for keeping European options open as new Mars missions were added to the international lineup.

Since that time, as ESA foresaw, the U.S. Mars exploration program has shifted its near-term focus for the next major venture from a sample return mission to the Mars Global Network mission. In recent informal dialogues, ESA has expressed a strong interest in this project.

Beginning this past July, an ESA study team was established to investigate the rationale and science opportunities related to lunar exploration. The $600,000 study will take place over the next year, with plans to make recommendations in a report similar to the one produced last year for Mars.

EUROPEAN SPACE AGENCY

Europe's near-term sights are set on Earth orbit. The Hermes spaceplane (above) would ferry astronauts to space station Freedom, one of three elements (along with a polar platform and "man-tended free-flyer") that make up the European Columbus program (opposite page).

Human Factors

ESA's contributions to life-science research will be enhanced when the Columbus laboratory module joins the Freedom space station in the late 1990s. In the meantime, European researchers have begun ground-based investigations on psychological and other factors related to long-duration spaceflight. At a recent conference, ESA representatives announced their participation in studies of an international team that spent six months in Antarctica. The tests focused on psychological factors as well as the bacterial environment in an isolated, self-contained facility.

Additionally, researchers in Norway and in France are pursuing a variety of underwater tests designed to simulate conditions in space. The tests will subject divers to a range of experiences to investigate such factors as performance, closed ecological systems and cultural differences.

Japan

Like Europe, Japan's near-term attention is focused more on space station Freedom than on charting a course to the Moon and Mars. Still, in a press conference held at the Japanese Embassy in Washington this summer, Masato Yamano, president of the Japanese National Space Development Agency (NASDA), stated that his country's activities on Freedom will be "the bridge to cooperation in the next century."

Freedom is Japan's largest international program to date, representing a national investment of $2 billion. The numerous changes to the program in its early stages have not given Japanese officials a comfortable feeling about American commitment.

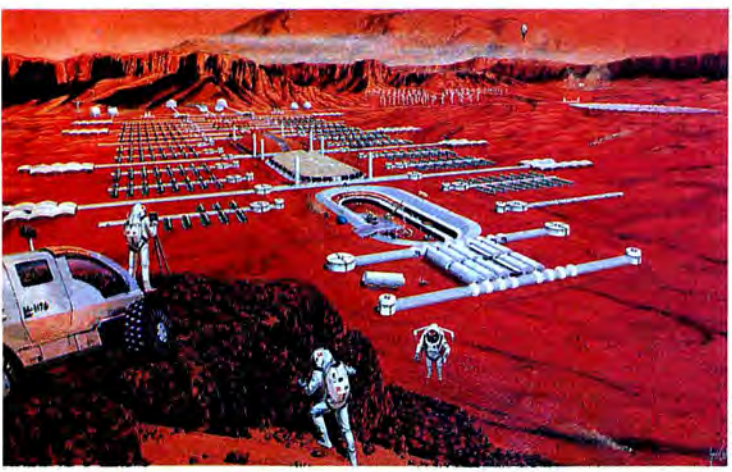
The Japanese spend $1.1 billion annually on space research—a fraction of what the Soviet Union or United States spends. Yet they believe the future of mankind is tied to space exploration and plan to more than triple their investment between now and the end of the decade. Add to that an expected $21 billion investment from the private sector, and Japan becomes a major space power.

The United States and Japan have enjoyed a successful track record of cooperative space activities, and they clearly would like this relationship to continue. As Yamano observed, "There is no doubt that the United States will continue to be Japan's major partner in space. We are determined to pursue this cooperation with the spirit of 'global partnership'."

A Japanese commitment to space already causes some in the U.S. space industry to be nervous. Will this be another case where Japan moves in and steals the show? The Japanese ability to form a strong partnership between government, industry and the academic community is reminiscent of America's success in building the team that took us to the Moon.

Although Japan's plans may intimidate people outside the country's borders, there are still questions regarding whether the Japanese public fully supports an aggressive space program. Historically, Japanese citizens have been extremely supportive of high-technology ventures. At the moment, however, there is not a groundswell of space support. NASDA's Yamano believes that this situation will change when Japanese astronaut Mamoru Mohri flies on a shuttle mission next year. Yamano believes that Mohri's picture will be on the cover of every major newspaper and magazine, developing a new sense of pride in Japan's space exploits.

The country's space activities are coordinated by three main organizations. An advisory committee to the Prime Minister, the Space Activities Commission, determines matters of policy and long-range planning. In June 1989, the Commission, chaired by Shiegebumi Saito, revised its Fundamental Space Development Policy. Looking ahead 10 years, the policy sets out guidelines that will enhance government-sponsored space technology and research capabilities, encourage wider public sector responsibilities and promote international cooperation.



OHBAYASHI

Responsibility for actual space development and operations goes to NASDA, which reports to the Science and Technology Agency. The agency's programs include development of communication satellites, the N and H series of launch vehicles, space station Freedom and the development of Hope, an unmanned spaceplane. More than three quarters of Japan's space budget is spent by NASDA.

The Institute of Space and Astronautical Science (ISAS) focuses on space-science activities and the development of the M series of solid-fueled launch vehicles. ISAS spends a mere $150 million annually, with a staff of approximately 125 scientists. The agency takes pride in the development of space projects that are small and beautiful.

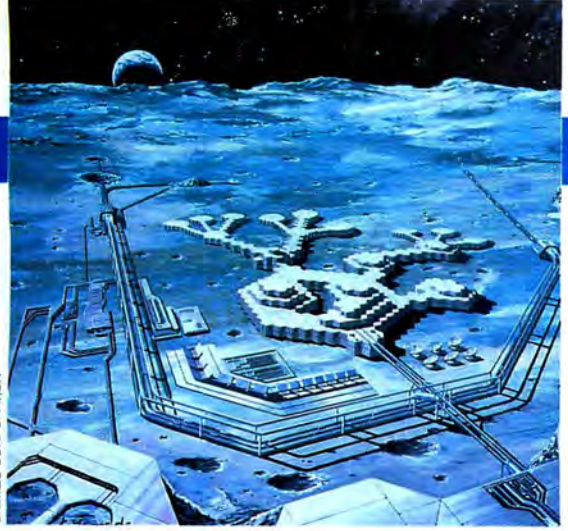
Space Station

Japan is pinning its participation in long-term human exploration missions to success on space station Freedom. The country's contribution to the Freedom complex is the Japanese Experiment Module (JEM), consisting of a pressurized module, an experiments logistics module, and an exposed facility. Current plans call for the launch of JEM in 1998.

Contributions from JEM to a human exploration program will primarily come from life-science experiments performed in the pressurized module and from robotics operations conducted with the exposed facility.

While the Japanese may have concerns about the outcome of space station Freedom, this has not kept them from dreaming of an independent national manned space station. NASDA has released contracts to five aerospace companies for studies of a separate Japanese Manned Platform. Specifications call for the station to accommodate a crew of three on 180-day rotations.

Contractors are to design this station with the capabilities of Japan's H-2 rocket (which is still being developed) in mind. With an



SHIMIZU CORPORATION

For long-range planning, Japan's private sector takes the lead. Opposite: An Ohbayashi concept for a Martian outpost. Above: Shimizu Corporation's Moonbase design.

assembly schedule of up to two years, it is estimated that a total of five H-2 rockets would be required. The objectives for the platform would include technology development for human exploration missions, as well as servicing satellites in geostationary and low Earth orbits. At this stage, the plans are not far enough along to quantify how this Manned Platform might contribute to a Moon/Mars program.

Robotic Precursors

Earlier this year Japan became the third country to take aim at the Moon, by sending the tiny Muses-A spacecraft into a lunar orbit. The mission, developed and launched by ISAS, is viewed by Japan as a small first step toward more ambitious Moon research. It was not a complete success, however—the data transmitter on a small probe released from the main spacecraft failed in lunar orbit.

ISAS recently proposed a follow-on mission for 1996 or 1997 that would drop penetrators into the lunar surface from an orbiting spacecraft. Sensors on the penetrators would measure temperature and seismology data, which would then be relayed back to Earth.

Both ISAS and NASDA are investigating missions to land rovers on the Moon's surface in the 1998-99 time frame. A NASDA version would be launched on the H-2 rocket, while ISAS is reviewing plans for a smaller rover to be placed in orbit with the M-5 rocket. NASDA has also initiated preliminary studies on concepts for a manned lunar base that would rely on habitats based on the JEM module developed for space station Freedom.

Finally, while most of the Japanese government's interest has been geared to the Moon, NASDA has initiated preliminary studies to investigate robotic missions to Mars.

Advanced Technologies

Japan's vast experience with robotics and computer technology could make a valuable contribution to an international Moon/Mars program. A proposal now under review involves the development of a robotic repairman for operation on space station Freedom. The device would use telerobotics and expert systems for operations such as assembly and maintenance. If the system proves successful with space station operations, it is expected that spinoff models would find applications at a Japanese lunar base.

Mission Studies

While government agencies concentrate on robotic missions, the most aggressive mission studies for human exploration are being conducted by Japan's private sector. Representatives from large construction companies such as Shimizu and Ohbayashi regularly attend and deliver papers at space conferences around the world. Shimizu has established a Space Projects office at its headquarters in Tokyo, where plans are being developed for everything from lunar mining to an Earth-orbiting hotel.

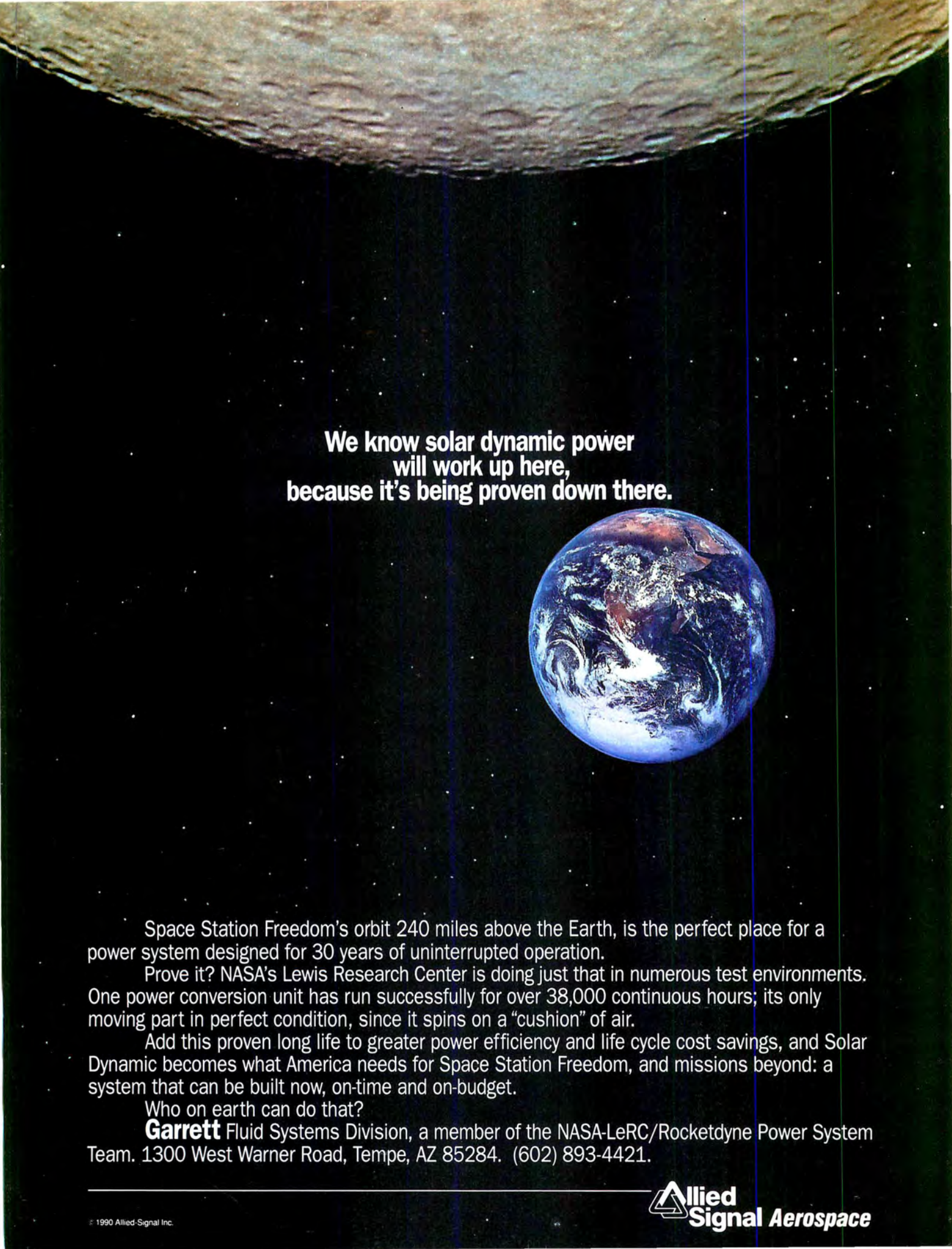
Japanese aerospace, electronic and construction companies are also active in sponsoring long-range studies through a think tank called the Future Technology Institute. The Institute is currently compiling ideas on innovative plans and rationales for a Moon base. A recent feature article in the Japanese magazine *Newton* displayed a whole range of full-color artists' conceptions for lunar base operations. Whether the country's private industry will make the kind of investment required to turn those drawings into reality remains to be seen. ■

MOON/MARS TIMELINE

YEAR	UNITED STATES	SOVIET UNION	JAPAN	ESA
1990	"Dialogue"	Mir	Muses-A	
1991				
1992	Mars Observer Lunar Prospector	Luna		
1993			H-2 Launcher	
1994		Mars 94		
1995	Freedom (Assembly begins)			
1996	Lunar Observer Mars Network	Lunar Rover/Sampler Phobos Sample Return	Lunar Penetrator	
1997		Mir 2		
1998		Mars Rover//Sampler	JEM Module Lunar Rover	Columbus
1999	Freedom (Assembly complete)			Hermes
2000		Lunar Laboratory		
2001	Mars Rover/Sampler			
2002				
2003				
2004	Lunar Laboratory			
2005				
2006				ESA Space Station
2007				
2008				
2009				
2010		Human Mars Mission		
2019	Human Mars Mission			

Key: Approved Missions
Proposed Missions

Alan Ladwig is a freelance writer and contributing editor to Final Frontier. *Before leaving NASA in 1989, he served in the agency's Office of Exploration. Terri Vogt Ramlose is a senior technical writer with Science Applications International Corporation (SAIC). She has contributed to several recent NASA reports on future space exploration, including* Leadership and America's Future in Space *and* The Report of the 90-Day Study on Human Exploration of the Moon and Mars.



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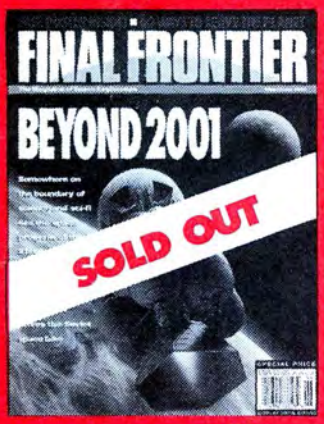

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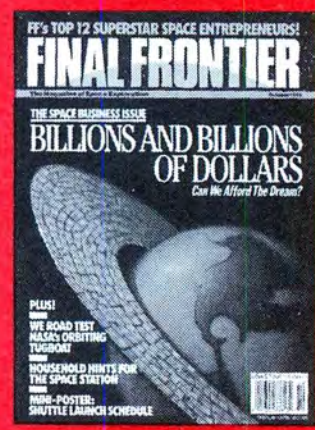

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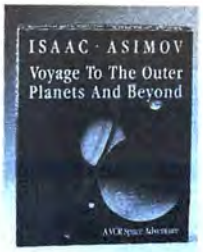

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FROM THE IMAX FILM *THE DREAM IS ALIVE*, COPYRIGHT SMITHSONIAN INST. / LOCKHEED CORP.

AFTER THE PARADES

When the space shuttle returns from a spaceflight, it stinks. The toilet hasn't been flushed for a week or more—and it was used by five to eight people. The odor of garbage may be rising from the "wet trash" storage compartments under the middeck floors. The walls, floors and lockers are coated with bits of juice, soap and dried-up bits of crud.

And that's just the inside. Outside, the orbiter has really been clobbered. At launch, rockets with the explosive force of a small nuclear bomb blasted it from zero to 17,500 miles per hour in eight minutes. During re-entry, parts of the orbiter were heated to 10,000 degrees. Pieces of ice, sand and pebbles have whacked it in a thousand places, and its engines—which have been thrusting at huge pressures, igniting and shutting down with meticulous accuracy—are completely spent.

A crowd of fans and VIPs cheers the return of every shuttle flight, and the crews always look happy as they bounce down the ramp to terra firma. But what awaits NASA workers after the television cameras turn off and the parades go away is, well, lots of work.

And when unexpected problems crop up, like the fuel leaks that grounded Atlantis and Columbia this summer, the work can be interrupted by frustrating, expensive and often embarrassing delays.

Countless tasks, major and minor, must be completed before the shuttle can be rolled out to the pad for another launch. Tens of thousands of highly skilled workers at more than a dozen facilities across the country labor for months to get a shuttle ready to fly again, at a cost of billions of dollars a year. Together, these workers—from large companies like Lockheed and Rockwell as

EVEN IN THE BEST OF TIMES, IT'S A TOUGH JOB GETTING THE SHUTTLE READY FOR ANOTHER FLIGHT.

MARK USCIAK

By Alcestis R. Oberg

Refurbishing an orbiter was a mightier challenge than anybody thought....Workers must be prepared to shift gears quickly.

TOM USCIAK

well as many smaller subcontractors—form what may be the world's largest pit crew, for what certainly is one of the most complex machines ever built.

But the effort to get the shuttle back in orbit doesn't begin at a furious pace. If there are time-critical experiments onboard, they're unloaded right after the shuttle's landing at Edwards Air Force Base. Otherwise, though, the shuttle is closed up.

That's right. The door is shut on the full garbage compartments and the overfull toilet. Then the orbiter is towed to a corner and left to sit in the desert heat, sometimes for a week or more, until the weather is right to fly it back to Kennedy Space Center in Florida for cleaning and refurbishment.

By the time it gets to Kennedy and is unloaded from its perch on the 747, the shuttle doesn't stink anymore. It reeks.

The potty, the galley and the space suits are removed in Florida and sent to Houston for freshening up. The solid rocket casings are fetched from the Atlantic right after launch and refurbished in Utah. Rocket engines are removed in Florida and some parts are sent for work in California—to be tested later in Louisiana.

To reuse a spacecraft, you first have to eviscerate it. Rocket engines and computers are swapped out so frequently that the shuttles become like frozen chickens that wind up with someone else's vital organs.

It's not just the smaller segments that get moved around. After five flights, the OMS (Orbital Maneuvering System) pods that bulge beside the tail are taken off for a complete check in the Kennedy Center's Hypergolic Maintenance Facility, where the small rockets that steer the shuttle are also checked out. Spacecraft motors sometimes require x-ray scrutiny in a separate facility nearby. Every three years or so, an orbiter is sent back to the factory in California for a complete structural inspection and sometimes major modifications.

Some shuttle equipment is never reused or is used only a few times. The big orange external tank—billed as the biggest throwaway soft-drink can in the world—is dropped into the Indian Ocean after each flight, never to be seen again. The tires are never reused, and until very recently the brakes weren't either. The vital turboprops that spin at a rate of 30,000 rpm, pumping oxidizer to the main engines, are refurbished only three times before retirement. So far, an unrefurbished, unrebuilt turbopump has flown just once.

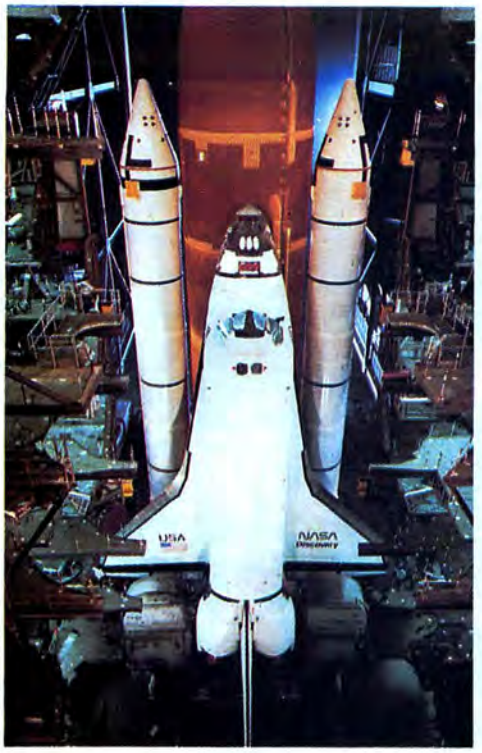
How much of an overhaul does the shuttle need? That depends on two things: how long it's been since the last servicing, and how much of a beating it took on its last ride into space.

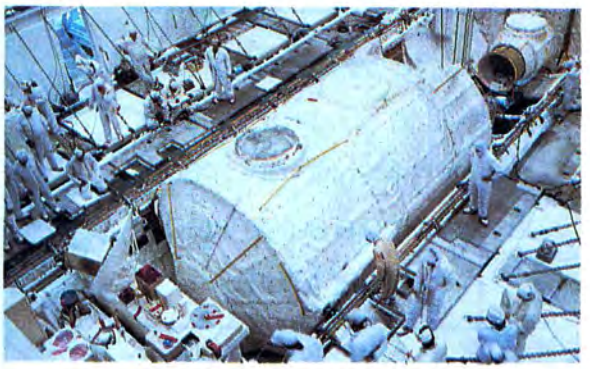
The Shuttle Garage

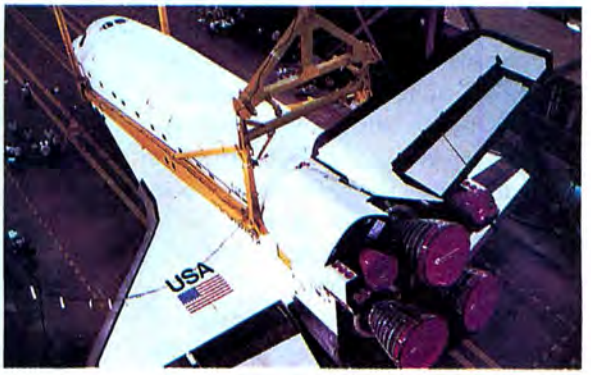
Most shuttle refurbishments occur in the Orbiter Processing Facility, or OPF—a high-tech, two-orbiter garage. Although the ceiling is 195 feet high, it feels positively cozy in there because of the clutter of platforms and gantries. "If you're standing in front of the building just before the shuttle is towed in, you'd see almost an outline of an orbiter in steel," said James Towles, director of Facilities Engineering at Kennedy. "They have to set the orbiter down in exactly the same place every time because we use a six-inch clearance around all flight hardware and the workers have to be able to reach every inch of the orbiter."

This may be the most cluttered garage in the world, but it's also the cleanest. Shoe-wiping machines are set up at all the doors to prevent street dirt from getting tracked in. If you're wearing dirty athletic shoes you can wind up in a comical tug-of-war with these stubborn little machines. In some areas—the shuttle cabin, for instance—people are required to change into static-free "bunny suits" for added cleanliness.

Tile workers aren't required to wear bunny suits, but they wear goatskin or cotton gloves when working on the tiles. They also use respirators on certain repairs







After returning to Florida on the back of a 747 (page 42), the orbiter is rolled (left) into the cavernous Vehicle Assembly Building and mated to its external fuel tank and solid rocket boosters. Top: a Spacelab module is assembled inside the shuttle cargo bay.

to keep from inhaling tile dust.

Originally, the famous tiles were used over the entire orbiter for thermal protection. But tile repair proved very time-consuming, and the orbiters only needed them on their bottoms, their leading edges and a few other critical areas, like the payload bay door hinges. The leading edges of the wings and nose are shielded with very expensive carbon-carbon tiles that are bolted on in segments rather than glued on individually. Less critical areas—the top surface of the wings, the mid sidewalls and the vertical and upper elevons—are now covered with special thermal blankets. A felt-type material is used for the very top parts of the payload bay doors.

Gluing on an insulation blanket or a tile takes the same amount of time, but the blanket covers a much larger area. The white insulation blanket is a soft, flexible spun-silica fabric trimmed to the size of a doll blanket or a scarf, not quite a square yard. The fabric is fitted to a spot, bonded there, stitched to adjoining blankets in some areas, and then painted with a precisely measured silica coating that cures to a glass-like hardness.

Some 500 to 1,000 tiles are apt to be slightly damaged on each flight. Most can be repaired in place. A small ding in a tile is drilled out with a dental drill and filled with a black paste, then sanded flush after the paste hardens. The job takes about three hours per tile.

About 100 to 150 tiles are usually damaged beyond repair, and replacing them is a more intricate job. Often they have to be "flossed" out using an electrically heated, piano-type wire slipped into the tiny gaps between them. A razor-sharp hacksaw may also be used, though workers must take great care not to damage the actual fuselage, whose curved shape makes the job even dicier. Afterward, a putty cast of the cavity is sent to Rockwell, which machines an identical copy. Ordinary tiles may cost anywhere from $800 to $4,500 apiece.

Bonding in the new tile is also meticulous, critical work. A laser tool is used to measure the microscopic gaps between tiles; this is no place for guesswork. "If you don't get it right— especially around the landing gear door and the external tank attach points—there's no tomorrow. You'll lose the vehicle during re-entry," said tile worker Rick Potter.

The 187 certified tile workers are overseen by a small army of engineers, quality-control inspectors and supervisors. Tile repair takes anywhere from 40 to 60 days—a task that isn't likely to get much easier or more automated in the near future.

Meanwhile, many other jobs are underway, all of them just as crucial. Various technical teams are preparing the payload bays for future missions, refurbishing rocket engines, inspecting the electronic and avionic systems and replacing a multitude of parts.

A quarter of a million spare parts for the shuttles are housed in an enormous "logistics" building overseen by nearly 500 people. "Logistics folks are the unsung heroes of this business," said

Tile repair takes anywhere from 40 to 60 days—a task that isn't likely to get much easier or more automated in the near future.

TOM USCIAK

James Towles. They track inventory, order parts, document failure rates for certain pieces and oversee the massive chore of simply locating the one gizmo among many thousands that someone needs. A computerized retrieval system helps them fetch the small items like screws, nuts and bolts. A "man-aboard" apparatus that resembles a big forklift can be used to haul out the larger items.

"Flow managers" who oversee the whole process—making sure all the thousands of component systems are ready and assembled by the time the shuttle leaves its OPF garage and goes to the huge Vehicle Assembly Building for "mating" with the solid rockets and external tank.

Orbiter On A Hook

Most people who enter the Vehicle Assembly Building for the first time experience an almost religious feeling. The VAB is one of the biggest buildings in the world—its roof covers seven and a half acres. And like the grand structures of the past—the Pyramids, the Parthenon, the Gothic cathedrals—this building has seen much history. All the rockets that went to the Moon were assembled here, along with all the shuttles. The VAB's pylons extend 120 feet down through Florida swamp into the bedrock; the immense structure could shelter a shuttle through a hurricane.

In the early days, when they turned on the air conditioning, misty clouds would form at the ceiling and it would begin to rain inside. The problem was solved by adding more ceiling insulation. On hot days, the huge interior space can be cooled using the "chimney principle." With a low window or door opened on one side of the building, and a tall window at the top of the other, heat is sucked upward. The windows shed a golden light that falls across the aisle, like rays streaming through the windows in a cathedral. Outside, just above the open windows, chicken vultures soar on the venting thermal updrafts.

The shuttle orbiters are brought into this enormous space down the lofty center aisle. Extra external tanks and solid rocket segments are stored on the left side. On the right—or seaward—side, two huge bays are dedicated to the actual mating and assembly of the vehicles. This process begins with the stacking of the two long solid-rocket segments. Then the orange external tank is lowered between them. Finally, the shuttle is lifted from the center aisle and lowered into place two inches from its rockets.

It's an awesome, heart-stopping sight.

The crane operators must first raise the horizontal shuttle straight up with two huge hooks. The wheels are retracted and the doors shut over them. The shuttle is then hoisted again, this time toward the vertical, until its nose is pointed at the ceiling. The rear hook can now be removed; slowly the shuttle is raised even higher, dangling from the single hook, almost to the VAB's ceiling.

Very slowly, the operator rotates the wings 45 degrees, so they'll fit through a bay opening designed long ago for Apollo hardware. Then he slowly rerotates it straight and lowers it ever so slowly through the bay's many platforms. "Lowering it is probably the toughest job," said Tod Betar, a crane operator. "You're dealing with an inch or so on each side, and you've got a 90-foot wingspan. You have to depend on the observers placed on those platforms to make the right call."

Mating the shuttle to the rocket package takes 48 hours, only about two of which involve actual lifting. Just tilting the wings correctly through the bay opening demands two or three hours, and the final alignment with the rockets and tank may take eight hours. The crane operators have to be accurate to 1/128th of an inch. Imagine it: An enormous crane, a 500-foot-long cable, a huge spacecraft—

TOM USCIAK

They only come out at night: The "stacked" shuttle travels the eight miles from the VAB to the launchpad on top of a giant crawler platform (left). Opposite page: A tile technician works on repairs to the orbiter's underbelly.

and accuracy almost beyond human eyesight.

Yet the crane operators rely on human judgment and skill, not laser guidance or computer assistance. The whole operation is one big balancing act between a huge vehicle with a mind of its own and a crane that has to move to offset the orbiter's motion. "You have to start and stop the shuttle without getting more than a fraction of an inch of swing," Betar said.

The different cranes have idiosyncracies, too. "The crane in Bay 1 will move real smooth east and west, but to the north and south it takes off a little faster and you have to have a little better touch for it. The crane in the other bay works real well up and down—it's very tight, to 1/128th of an inch. We compare all our cranes to that one. It's 25 years old, and our newer cranes don't work as well. It's great."

Several people work on the crane during lifting: an observer and two operators as well as an emergency-stop operator. One operator moves the shuttle in the north, south, east and west positions, while the other controls up and down motion and swiveling. The others are on the ground watching everything, and there are spotters talking the shuttle down through the various platforms in the bay.

A crane operator needs three to five years' experience and training before being allowed to run the crane that holds the entire American manned space program suspended from one hook. "It's a very nerve-racking job," agreed Betar. "The first time I walked in, it was pretty awesome. The size of everything—how big everything was and how accurately everything was being moved around. The older guys try to crack jokes to take the edge off. But it gives you a great feeling afterward, and you say, 'Wow, I *know* there aren't 200 people in the world who have done this!' In a sense, I just flew the orbiter—it's almost as good as riding in it."

Learning The Road

The shuttle and its mobile launchpad hitch a ride from the cathedral-like VAB to the launch site on a "crawler"—another Apollo-vintage engineering marvel, a cross between a barge and a tank. The crawler pulls right under the mobile launch pad and roars out of the VAB like a locomotive, always in the dead of night when the winds are calmest. The upright shuttle sways a bit as it crunches down the rock-strewn road.

"There's no 'driver's ed' for these things," said Bill Tootill, one of the crawler drivers. "So when they're moving the crawler—without a shuttle on top—from place to place, they get you on a straightaway somewhere and let you drive. The first time, you tend to 'S' down the road because you haven't figured out your reference points yet." The controls involve several knobs and gauges, a foot brake and a small steering wheel about eight inches across. The drivers "learn the road" like Mark Twain learned the river while training to be a steamboat pilot: "The crawler's overall operation is controlled by an extensive document—what activities take place and when," said Tootill. "But driving it down the road...well, you can't write a book about it. You just have to look out the window and drive it."

Nobody's ever driven off the special crawler-way. "It's as wide as the New Jersey turnpike!" said Tootill. But a few curves can be tricky. "There's a very tight turn to Pad B," Tootill noted."The crawler is designed to turn in a 500-foot radius, and whoever designed that turn designed it at exactly 500 feet. If you hit it wrong, then you may have to back up and get at it again." The crawlers have a "crab mode" that allows the vehicle to "sneak over" and move sideways if it comes into a turn wrong.

When the designers thought about getting the spacecraft from the VAB to the launchpads—eight miles away over boggy land—they considered floating them across, or setting up a rail system like the Soviets have for their rockets. But a barge, NASA reasoned, could sink, and a rail system would be costly to maintain.

The solution—a crawler-way—is not exactly your normal highway. Few roads could take the 17-million-pound load of shuttle, launchpad and crawler; asphalt would disintegrate, and the crawler would

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bog down in gravel and sand. This special roadbed is eight feet deep: three feet of shell, two and a half feet of limestone, a foot of asphalt, and the top eight or more inches of river rock. As the crawler and the slightly swaying shuttle take their midnight ride to the pad, the river rocks are crushed under the treads, lending traction and stability. When the river rocks are crushed to sand, the road is topped off with more rocks.

The crawlers' top speed is about one mile an hour, and they can never turn around. So, like a ferry, the same side has been facing the sea ever since they first went into service 25 years ago. The odometer on one just went over 1,000 miles.

But even these behemoths—which have been designated as National Mechanical Engineering Landmarks—have their limits. You can't change speeds too quickly or the automatic leveling system will panic and shut everything down. "It's like if you take a glass of water and move it back and forth—it starts to slosh," said Tootill. "And if it sloshes too much, it drops the whole system off line and you're done. You sit in the middle of the crawler-way four or five minutes to start up again. I did it myself once. It's very embarrassing."

The crawler crew usually includes 18 people—diesel mechanics in the engine room, others in the pump room, four technicians keeping an eye on the treads, three drivers, a jacking and level operator and backup crews. There's one porta-potty to accommodate the entire bunch on the all-night trip to the launch pad.

The most worrisome part of the trip for a crawler driver is the end. The approach into the tight tangle of launchpad platforms is done partially by laser guidance, partially by human judgment, and, on rare nighttime approaches, with the aid of yellow rope laid on the ground and illuminated by flashlight.

The crawler ride can inspire awe, even among old hands. "Several rollouts back, we had a full Moon when we rolled out," said Tootill. "During a break, I looked at the orbiter in the moonlight and let my mind wander. It's wonderful. And last year when Hurricane Hugo was out there, we thought we might have to move the shuttle off the launchpad. That night we went up. They had the platforms rolled back so all you saw was this brilliantly lit shuttle and solid rockets against the black velvet sky. I drove up this hill and this thing was right in front of me—and for a few moments there, my concentration went to pot. It was very beautiful."

The drivers are all college-educated mechanical engineers who supervise by day and drive by night: "This is the type of thing you tell your grandchildren about," said Tootill. "There's nothing bigger than this, except maybe the QE II. There are hundreds of astronauts, but only eight crawler drivers in the world."

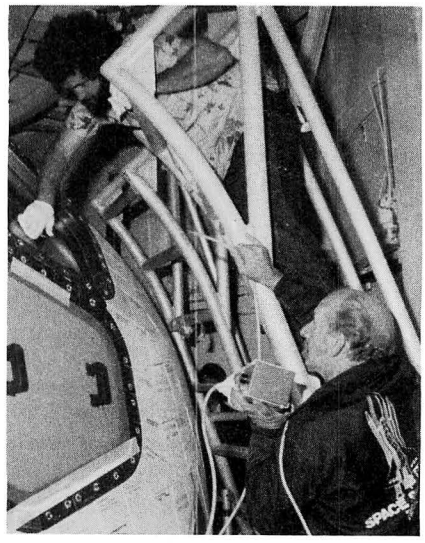
Launchpad Life—And Death

The launchpads are the most dangerous places to work at Kennedy. "Every gas system out here is at 3,000 pounds of pressure, so if you make a mistake, that line could wrap around you very quickly," said Buzz Brown, Launchpad B manager. "We're constantly raising and lowering platforms, and dealing with caustic and toxic propellants."

People who work at the pad are usually licensed aircraft industry workers, and some have licenses and certifications in handling toxic fuels and chemicals. There are 120 full-time workers assigned to launchpad duty. Though safety gear is mandatory and safety procedures are strenuously followed, accidents can happen. A fatal mishap occurred in 1981.

"Two guys were killed when they went into the aft end of the orbiter when there

continued on page 58



Cleaning the shuttle's windows on the pad.

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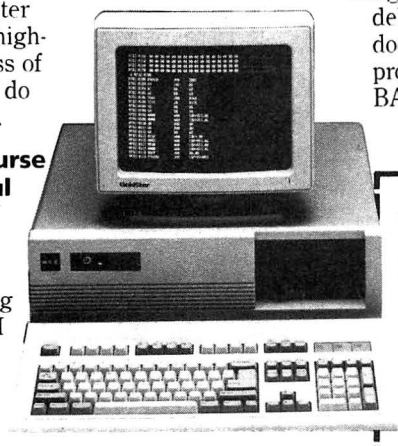

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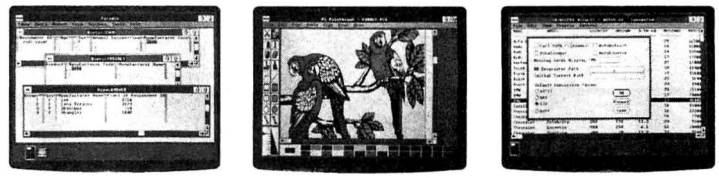

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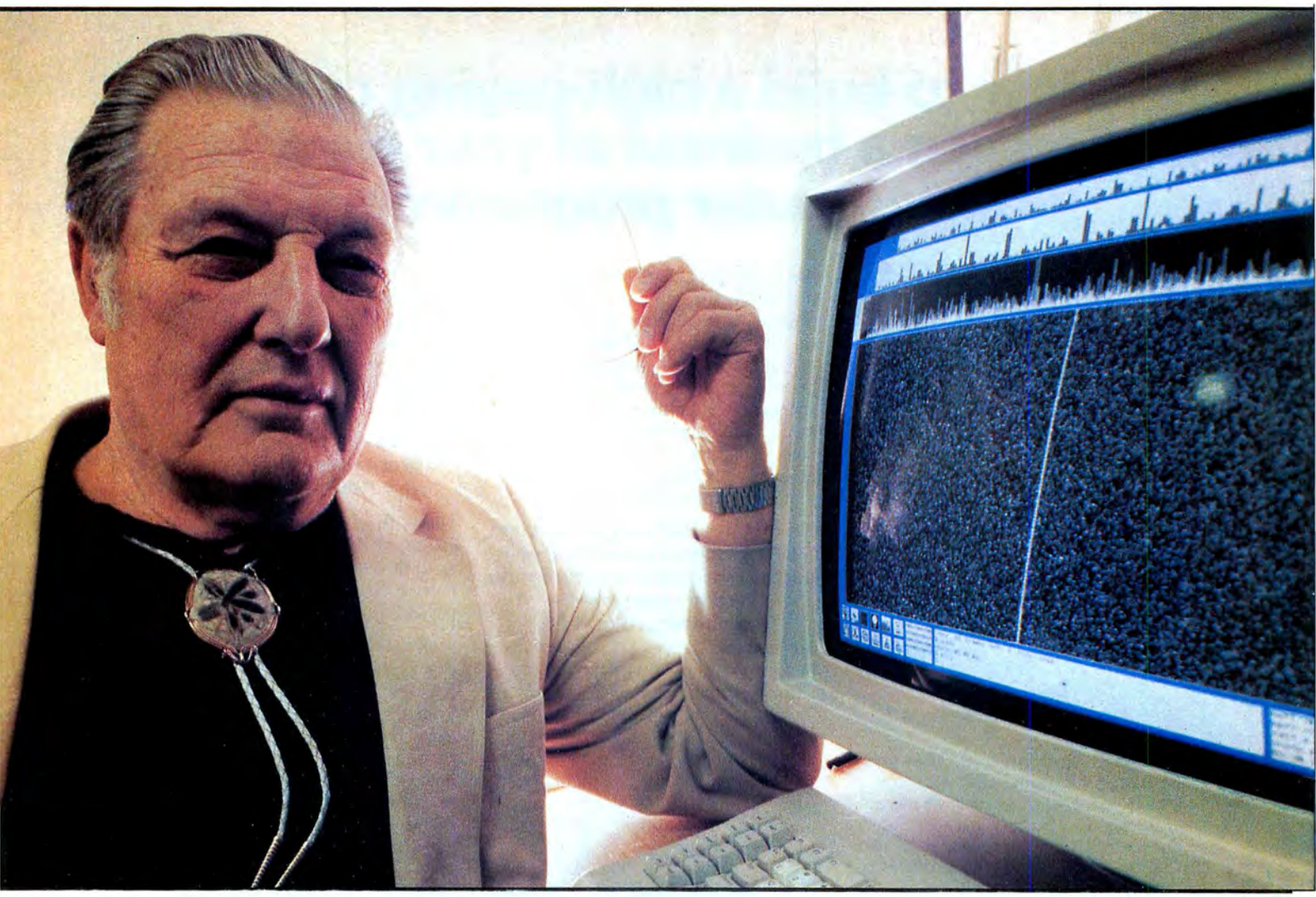

SETI's Grand Old Man

Barney Oliver has never been shy about getting acquainted with his far-out neighbors.

By Charles Petit

JERRY TELFER, SAN FRANCISCO CHRONICLE

Barney Oliver is big and often gruff. He has a bad knee, drinks gin when he likes, nods off when he's bored, and is old enough and rich enough to do anything he wants. He cannot abide wishful or fuzzy thinking, and he may frighten those who are intellectually timid. He is as hard-nosed and practical an engineer as one can find.

All in all, this deeply conservative man is not the sort one would expect to be a visionary or a romantic, or to have ideas about making contact with aliens. But he is, and he does.

Bernard M. Oliver, 74, is deputy chief of the SETI Microwave Observing Project at NASA's Ames Research Center in Mountain View, California, some 40 miles south of San Francisco. He would probably still be the chief if he'd stayed on the payroll full-time, but these days he's content to be the deputy to British-born John Billingham, an old friend and fellow pioneer of SETI, the Search for Extraterrestrial Intelligence.

"I'm a four-tenths civil servant. The rest of the time I am not so civil and never servile," he says over lunch at the easygoing Palo Alto Club near Stanford University, where old men play liar's dice and a sign that has since fallen from the wall once read, "The Purposes and Aims of this Club are to have No Purposes and Aims."

Barney Oliver *does* have a purpose and an aim, however. To date, his chosen field of SETI has produced zero data—or, more exactly, plenty of data, all of it null. But if SETI ever turns up one honest-to-Spock datum, one purposeful radio signal from a nonhuman civilization, the payoff will be immense. We'll know that someone else is out there.

Oliver explains his devotion to SETI with a typically straightforward appraisal. "Of all the big questions facing mankind, this is the one that involves technology I know well." If there's any single thing he'd like the general populace to understand, it is that our Sun is a star, part of a cosmos not so different from what we see nearby, and that we probably do have neighbors out there. Asked what he's good at, he replies, "I guess I'm a generalist. I like to solve problems and use ideas from one sphere in another."

Oliver generalizes instinctively. He designed a system for his house that circulates hot water constantly through the pipes by convection, so that hot water immediately flows out when one turns the faucet. He modeled it after concepts in electronic circuitry.

He has a business on the side called Biosys, Inc. that develops nematodes, exceedingly simple organisms, as natural pesticides. A nematode "is a featureless worm," he says, "with a mouth, an anus, a gut, sex organs and nothing else." Its simplicity and capacity for adaptation appeal to him. Looking for other intelligent beings is, for Barney Oliver, an ultimate act of faith that life on Earth is not unique, but simple at heart, part of a general tendency. If there are nematodes here, why not the equivalent elsewhere? And where there are nematodes, why not intelligence, too? For Oliver, the answers to these questions are quite simple.

Oliver's inventive genius for electronics—and his personal and political connections—are major reasons why, after 30 years of shoestring efforts, NASA is in a position to start putting real money into SETI. Congress may have other ideas, however. In June the House deleted SETI's entire $12 million allocation for next year, which may or may not be reinstated by the time the space budget is finalized this fall.

If NASA's plans hold, sophisticated signal analyzers will be hooked to radio telescopes in the United States and elsewhere, beginning on Columbus Day 1992, half a millennium after Europeans began invading the New World. Within 30 minutes, they will explore a greater portion of the radio spectrum, with greater sensitivity, than have all the dozens of SETI efforts to date.

The spectrum analyzers are descendants of a scheme Oliver helped to hatch nearly 20 years ago. Each will parse a portion of the microwave spectrum into as many as 14 million channels, scanning the radio sky for sense amid the gibberish produced by quasars, neutron stars and other astrophysical objects. Kent Cullers, an astronomer and signal processing expert, works closely with Oliver on the SETI project. Cullers describes it as "searching the equivalent of the *Encyclopedia Britannica* every second to find the part that says 'Hi, we're the aliens.'"

Two NASA centers—Ames and the Jet Propulsion Laboratory (JPL) in Pasadena, are in on the SETI program. The Ames team, which is in overall charge, will aim receivers at 1,000 or so nearby stars (within 80 light years) to try to detect either stray intelligent signals or weak beacons. The JPL group will survey large patches of the sky looking for super-powerful beacons that might have been built by distant mega-civilizations. Meanwhile, a separate facility, the SETI Institute in Mountain View, will handle many of the administrative chores.

Even the most optimistic SETI backers say that a fair shot at success will take many years of lightning-fast data processing. The spectrum is wide, the stars are many, and the universe is cacophonous. There may be thousands of alien microwave signals in the galaxy, but they could easily have been overlooked thus far by radio astronomers. If initial efforts yield little, SETI could keep growing, eventually requiring a huge array of special antennas. The cost could soar to many billions of dollars. But given that kind of investment, current technology is capable of detecting the stray signals of another Earth halfway across the galaxy.

The SETI project has suffered lean years. It has endured confusion with UFO-mania (even though flying-saucer devotees are treated with contempt at the SETI office). Oliver and Billingham nearly saw the NASA SETI program die altogether in the late 1970s and early 1980s. Back then, former Wisconsin senator William Proxmire gave it his Golden Fleece Award for wasteful federal expenditures. Proxmire even got language into NASA's appropriations bill to explicitly forbid spending on SETI work. Billingham found unspent money from the previous year to keep the project alive, but only a plea from astronomer Carl Sagan to

Proxmire prevented its eventual demise.

The attacks keep coming, though, and they've taken their toll on Oliver. "You can see his frustration," says Jill Tarter, a Berkeley-trained astronomer and chief scientist at the Ames SETI project. His feeling, she said, is "I'm tired. I hurt. I want to see SETI in action before I die."

Oliver spent much of his career with the Hewlett-Packard Corporation, where he rose from being one of the earliest employees to sitting on the board of directors before he retired in 1981. Today, many of us carry around in our pockets, purses or briefcases a legacy of Oliver's work at Hewlett-Packard. In 1971, while vice president for research, he led the team that invented the pocket calculator. Oliver pushed the project despite a marketing report (HP cofounder Bill Hewlett insisted on one) that concluded nobody would buy the thing, that it was just an overpriced toy.

There are other legacies: The rapid transit trains in San Francisco's BART system run better because Barney urged changes in its automatic switching and control system. He provided key concepts for the control system of the Keck 10-meter telescope, which will be the world's largest when the University of California and Caltech finish it next year in Hawaii. University of Arizona astronomer Tom Gehrels even named an asteroid after Oliver, who helped design equipment to search for asteroids passing near Earth.

Oliver is a member of the National Academy of Engineering as well as the National Academy of Sciences. He was president of the Institute of Electrical and Electronic Engineers. He has a mess of patents to his name and a pot full of prizes, right up to the National Medal of Science from President Reagan in 1986. After getting the 1986 award he took a tour around NASA headquarters, where people told him what a great scientist he was. "Gee," he said. "I thought I was an engineer."

Recently, Oliver explained to writer John Joss of *Silicon Valley Engineer* magazine the difference between science and engineering. "Discovery is the fruit of science, invention the fruit of engineering. They're different—scientists are curious, analytical, they wonder about our universe; engineers, on the other hand, are creative—they want to synthesize, do the 'sweet' job, exercise their craft."

In other words, Oliver can't help trying to fix things. A secretary at Hewlett-Packard came in one Monday to find her typewriter in pieces. Barney had worked over the weekend and decided to repair it. A jazz fan and accomplished pianist, he became frustrated some years ago with the poor quality of commercial stereo speakers. So he built his own. According to Vera Buescher, his long-time assistant, "the engineer in him just never shuts off."

Oliver is perhaps most notorious for fixing other people's grammar. He is remorseless with speakers who confuse lie with lay, or flub a subjunctive. Barney himself describes the habit as a "mysterious compulsion" that stems back to his earliest experiences.

> "Of all the big questions facing mankind, this is the one that involves technology I know well."

An only child, he spent his childhood far from town (home was a 160-acre ranch on California's hilly central coast) and turned to his imagination for entertainment. He grew up with a big perspective on life and the universe, and was introduced to the moons of Jupiter and the craters of the Moon through the eyepiece of his engineer father's surveyor's transit. His passion for precision came from his mother, who took him at age four to study phonics and fractions in Aptos Grammar School, where she was both principal and the only teacher.

A love of learning, and an ability to stick to ideas and notions with a joyful stubbornness, have never left him. Charles Seeger, a SETI project astronomer (and brother to folk singer Pete Seeger), recalls the time a few years ago when Barney "came in and said he spent the whole weekend seeing if he could, from memory, reconstruct all the 20 basic theorems of geometry. And he did it."

Oliver got his Ph.D. in electrical engineering from Caltech in 1940, and spent the war years working mainly on radar gear and television at Bell Telephone Laboratories. His radar work led to his first thoughts about extraterrestrial communication. "In about 1948, just for the hell of it, I computed what the one-way communication range of a standard radar would be," he recalls. "I was astonished with the results. With a five-foot dish you could communicate with another radar out to interstellar distances. I said to myself, 'son of a bitch'."

Speculation about otherworldly civilizations goes back centuries, of course, but the modern SETI effort has its roots in the mid-1950s, in writings by scientists including Frank Drake, Philip Morrison and Giuseppe Cocconi.

Drake, now a professor of astrophysics at the University of California at Santa Cruz, attracted press attention in 1960 with his Project Ozma—an effort using the giant Arecibo radio telescope in Puerto Rico to try to detect alien signals.

A short time later, Drake was at work at the National Radio Astronomy Observatory at Green Bank, West Virginia.

"I got a call. This voice introduces himself as Barney Oliver. He said he was coming out to see me." Oliver didn't *ask*, Drake noted. "He just said he was coming."

A year later Oliver was a key member of a loosely chartered SETI group, the Order of the Dolphin, that included Drake, Carl Sagan, Soviet scientist Iosif S. Shklovskii, chemist Melvin Calvin and others. During the 1960s, despite his duties at Hewlett-Packard, Oliver managed to give SETI a lot of thought. Among other things, he concluded that direct contact with extraterrestrials was unlikely. He calculated the odds that another civilization might choose to actually travel among the stars rather than "explore" with radio signals. Even if their rocket converted matter to energy with perfect efficiency, it would require enough energy to satisfy American electrical demands for half a million years—just to carry a few crew members to the nearest star.

"Today we contemplate a universe teeming with life, some of which may be intelligent," Oliver has written in a justification for SETI. "It is nice to have scientists come to believe what science fiction fans have known all along, but the latter group is going to have to change its thinking, too.

GRASSROOTS SETI

THE PLANETARY SOCIETY

Planetary Society president Carl Sagan, with META researchers Colomb and Horowitz.

Today's most ambitious full-time SETI project is not being funded by the U.S. government, or by taxpayers anywhere, for that matter. Sponsored by the California-based Planetary Society, project META (Megachannel Extraterrestrial Assay) owes its existence to membership contributions and a $100,000 gift from film director Steven Spielberg, maker of *E.T.* and *Close Encounters of the Third Kind*.

This October, the Society will expand its search for alien life to the skies over the Southern Hemisphere. On Columbus Day, META II—a duplicate of the META system now operating in Massachusetts—is scheduled to be turned on at a radio telescope operated by the Argentine Institute of Radioastronomy, 30 miles southeast of Buenos Aires.

Why Argentina?

"Most SETI searches have been conducted in the Northern Hemisphere," says Thomas McDonough, the Planetary Society's SETI coordinator. "The southern sky happens to be more interesting in a lot of ways. Down there we can see other galaxies, such as the nearby Magellanic Clouds, and the center of our own Milky Way galaxy, a large concentration of stars that may be the best place to look for other civilizations."

When Raul Colomb, a radio astronomer at the Institute, answered the call for a Southern Hemisphere facility willing to take on the project, he and two associates were brought to the United States to study the existing META system and help build a duplicate. The $150,000 to construct META II came from the 125,000 members of the Planetary Society, which was founded in 1980 to advocate the exploration of space.

According to executive director Louis Friedman, the Society saw SETI as an opportunity to fund a project of enormous significance at a relatively low cost.

"What is particularly important to the Planetary Society is that we can make a difference with this very modest effort," Friedman said. "Ordinary people really can do something."

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continued on page 60

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Oliver takes comfort in this. "They can't get here," he says. "I don't think we're ever going to end up as a gourmet delicacy on some alien's breakfast table."

In 1971 Oliver and Billingham led a summer study workshop at Ames that is considered a milestone in the field of SETI. Two dozen scientists and engineers mulled over the complexities of detection strategy, receiver design and antenna size, and wrote a summary of what they called "Project Cyclops."

One illustration from the Cyclops report shows a field of hundreds of antennas, each more than 100 yards across, shoulder to shoulder in a circle nearly 10 miles in diameter. The immensity of this forest of dishes, and its cost of tens or hundreds of billions, has stuck in people's minds.

"I think that drawing backfired," says Seeger, a member of the study group. "People didn't read the report, and they think it's an all or nothing thing." In fact, that vast array is imagined as the *maximum* size Cyclops could ever have. The actual goal is to start operating with a few antennas, and build more if and when money becomes available. "You only build what you need," Seeger says. Such an array would also be immensely useful for standard, non-SETI radio astronomy.

NASA's current SETI project is much more modest, and envisions no such special receivers, although they may eventually be needed. It will piggyback the spectrum analyzers on existing radio telescopes. But it hopes to meet at least some of the goals set in the 243-page Cyclops report, still the bible of the field.

And if it does, Barney Oliver, for one, will be fulfilled.

In the book's forward, he wrote that "if the Cyclops report stimulates further study that results in a full-scale search, I shall consider this to have been the most important year of my life." □

Charles Petit writes about science for the San Francisco Chronicle.

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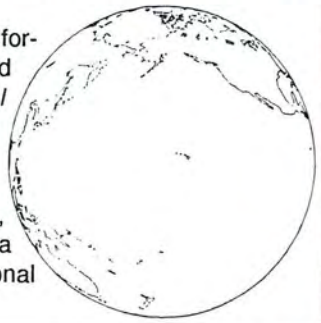

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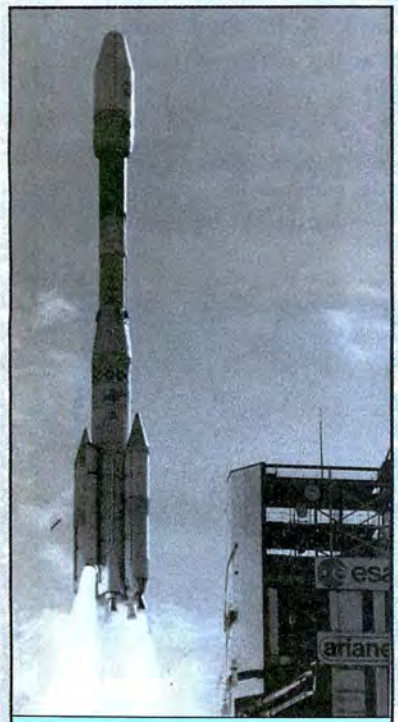

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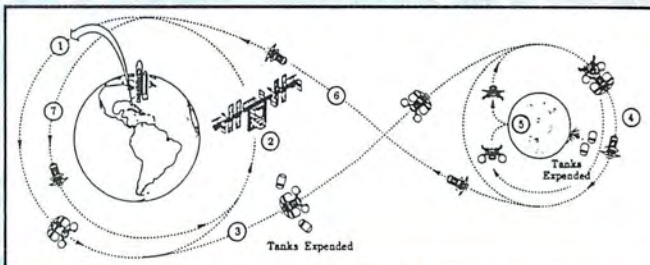

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SPACE CAPSULES

A record of space-related events, May-July 1990

May 23

Japan's Mitsubishi Heavy Industries announced the formation of an industrial consortium to launch and market the country's planned H-2 rocket, scheduled to make its debut in 1993. The new Rocket Systems Corporation pools the resources of more than 70 companies, which contributed a combined $3 million to the start-up. The H-2, meanwhile, continued to suffer teething pains: An engine fire July 11 was the latest in a series of setbacks for the homegrown rocket development project.

May 24

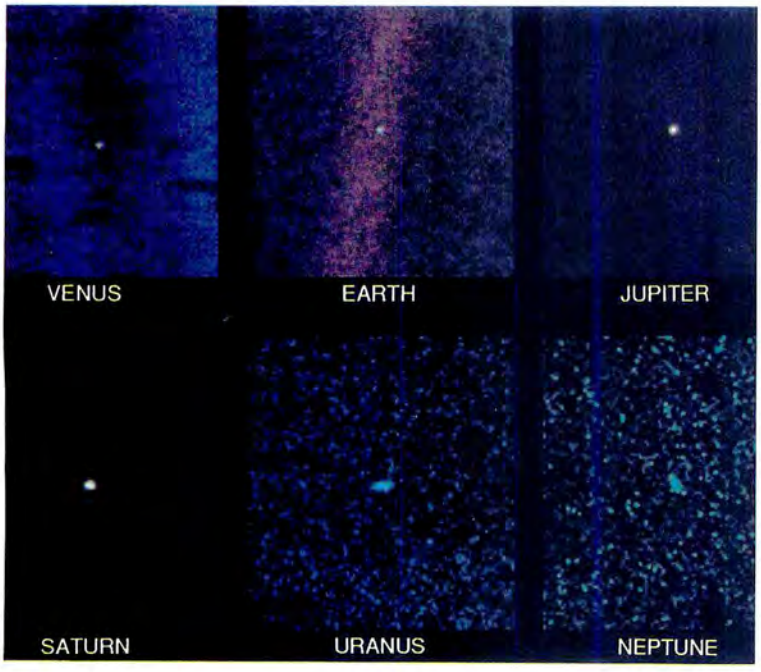
The Department of Defense and NASA approved a plan whereby five contractors would join their efforts in designing the U.S. National Aerospace Plane, or NASP. Rockwell International will lead the team, which includes McDonnell Douglas, Pratt and Whitney, General Dynamics and Rocketdyne. The companies will share information as they work to develop technology for a space-plane that could reach orbit after taking off from a runway like an aircraft.

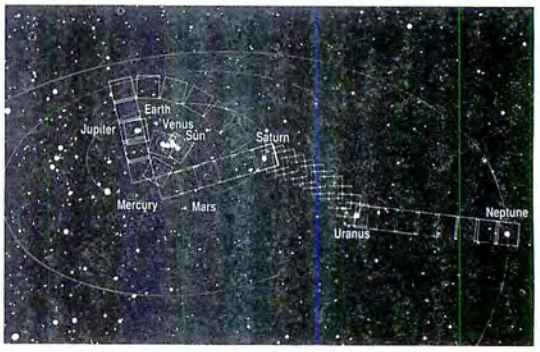
May 29

A month-long nightmare of bad publicity for NASA began with the aborted launch of the ASTRO-1 space shuttle mission six hours before liftoff, due to a leak in the connection between Columbia and its external fuel tank. The shuttle was rolled back from the launchpad two weeks later so that engineers could find the source of the leak, but that proved to be a frustrating search: In mid-July, the exact cause of the leak was still unknown.

June 1

The largest and most precise x-ray telescope ever sent into space—Germany's ROSAT (Roentgen Satellite)—was launched into a 360-mile- high orbit from Cape Canaveral onboard a Delta rocket. During its first six months in orbit, Rosat will map the entire sky at x-ray wavelengths, which are invisible to observers looking through the Earth's





February 1990: From a distance of four billion miles, Voyager 1 took this backward-glance "family portrait" of the Solar System. A total of 60 frames show six of the nine planets as little more than dim points of light.

atmosphere. For the rest of its two-year lifetime, the telescope will be used for detailed study of some of the 100,000 new x-ray sources that Rosat is expected to discover.

June 8

America's most powerful unmanned rocket, the Titan 4, made a successful second launch almost a year to the day after its inaugural flight. Onboard was an Air Force spy satellite. The Titan 4 can deliver as much as 39,000 pounds into low orbit, making it second only to the space shuttle (52,000 pounds) in terms of U.S. lift capacity. The Air Force expects to launch 10 per year by 1995.

June 10

After two tries and a delay of four days, the new "Kristall" materials processing laboratory was successfully docked with the Soviet Mir space station in orbit. Kristall, the third of Mir's add-on modules, had been launched to the station at the end of May, but a first attempt at docking on June 6 was aborted when a thruster malfunctioned. Besides adding room to the space station, the Soviets hope that research conducted on Kristall will help to make space manufacturing commercially profitable.

June 13

Three months after a commercial Titan rocket stranded its Intelsat 6 communications satellite in a useless orbit, the Intelsat organization agreed to pay NASA $90 million to go rescue it. According to current plans, space shuttle Endeavour will be sent (on its maiden flight in February 1992) to rendezvous with the orbiting satellite. Two spacewalking astronauts will then attach a new rocket motor that will boost Intelsat 6 into its proper orbit; Intelsat will get a "new" $150 million spacecraft, and NASA will get a chance to demonstrate the shuttle's versatility. On June 23, another Titan 3 delivered an identical satellite into orbit for Intelsat without incident. By early July, Intelsat lawyers were embroiled in a legal battle with the Titan's manufacturer, Martin Marietta, over liability for the March 14 failure.

June 27

NASA's Nightmare, Part Two: Project officials for the Hubble Space Telescope announced their discovery of a "spherical aberration" in the newly orbited telescope's mirror that prevents it from focusing light properly and renders at least two instruments that observe in visible light virtually useless. By mid-July, the evidence pointed to a manufacturing error in shaping the 94-inch primary mirror. While embarrassed NASA officials paraded before angry congressional committees and named a task force to look into the foul-up, project engineers and astronomers worked on solutions. Replacement instruments, with optics that can counteract the effects of the warped mirror, will be installed by shuttle astronauts no later than 1993—restoring the telescope, according to NASA, to full operating capacity for the rest of its 15-year lifetime in orbit. In the meantime, the telescope will be used for ultraviolet and spectrographic studies not affected by the flaw in the mirror.

June 29

NASA's Nightmare, Part Three: Space shuttle Atlantis, which had been moved to the launchpad for a July liftoff in place of the leaking Columbia, also sprung a hydrogen fuel leak during a tanking test. This forced the space agency to ground its shuttle fleet until engineers could find the answer to two of the most perplexing technical problems in the vehicle's history. Three weeks later, both leaks—which, despite their similarity, had different causes—remained unfixed, but NASA managers were confident they could get at least one flight off by early September.

July 3

Space Services Inc., the company that in 1982 launched the first privately developed rocket from an island off the Texas coast, was forced to suspend operations and lay off most of its employees when the Houston-based Development Ventures Inc. withdrew financial backing. Although SSI has launched small sounding rockets for paying customers, its larger Conestoga vehicle has yet to make it into orbit. Former astronaut and SSI president Deke Slayton immediately began searching for a new investor, just two weeks before marking the 15th anniversary of his historic Apollo-Soyuz spaceflight.

July 8

On a Sunday morning news show, Secretary of State James Baker confirmed that the Bush administration had decided to open the way for the American-owned United Technologies Corporation to participate in building the proposed Cape York spaceport in Australia, despite the fact that Soviet rockets will be launched from the site. In Australia, meanwhile, the traditional Aborigine owners of the northern Queensland site were reported to be mounting a legal challenge to the project.

July 9

Astronauts David Walker and Robert "Hoot" Gibson, both of whom were scheduled to command shuttle flights in 1991, were grounded for violating a NASA rule that bars astronauts from participating in risky activities—including skiing and parachute jumping—while in training for a mission. Gibson had been involved in an aircraft collision during an air show two days earlier in which the other plane's pilot was killed. Walker was cited for a number of flight-related infractions. They were the first astronauts ever pulled from flight assignments for disciplinary reasons.

Upcoming Events

September 1

Magellan begins its eight-month mapping mission of Venus following a mid-August arrival in orbit.

October 5

STS-41 space shuttle mission launches the European Ulysses probe into a polar orbit around the Sun.

After The Parades

continued from page 48

was 100 percent nitrogen in there," recalled Brown. "One went in to save his buddy, and they both died. A third went in with protective gear on. In fact, several people jumped in and tried to save them."

Another time a fuel line broke loose and sprayed oxidizer over the belly of the orbiter, deteriorating some tiles. Fortunately, the workers were in protective clothing. They managed to reconnect the line and stop the propellant from seeping over more tiles.

Given the usual precautions, however, most launchpad operations are completed without incident. When a shuttle is in place, it takes about six hours to hook up all the lines and test the interfaces between the shuttle and the launchpad, and open up the vehicle—the crew compartment and the aft end—to make sure nothing was damaged or moved in transport from the VAB. The electrical power and instrumentation is mated to the mobile launcher beneath the shuttle, and the connections are made to the firing rooms that will ultimately launch the craft.

The shuttle sits on the launchpad for at least three weeks before it's ready for flight: The cargo is loaded in, the interfaces and equipment checked, the simulated countdown with the crew completed, and the engines successfully fueled. During the final "close-out," the orange fuel tank is loaded, and so are the explosive devices that set the shuttle free of the pad at liftoff.

In between launches, the pad crews must do extensive maintenance, repairing damage from the launches as well as from the salt air of the Atlantic. Some routine maintenance can be delayed when the schedule gets very tight—say, a launch a month. "We can do that for a while without sacrificing safety and reliability," said Brown, "but not forever."

Office space is at such a premium at Kennedy that there are even offices beneath the pads. These, of course, are vacated just before launch. Even though there's as much concrete in a launch pad as there is in seven and a half miles of four-lane interstate, the mighty shuttle main engines and solid rockets give the area a good shaking, and some ceiling tiles invariably come down. The first thing workers have to do when they return, they say, is put the "damn tiles" back up one more time. No one bothers anymore to hang things on the walls.

Payload Headaches

While the orbiter is being prepped for its next liftoff, another network of technicians is working just as meticulously on what the craft will carry. The space shuttle has delivered an enormous range of satellites, instruments, deep-space probes and space laboratories into orbit. Though each one has to fit into the payload bay and meet general shuttle specifications, some show up at Kennedy already assembled, others do not.

All shuttle payloads are handled, and handled gently, in clean-room type environments. Most shuttle cargo—probes, satellites, and so on—are assembled in a Vertical Processing Facility and loaded onto the shuttle at the launchpad very early in the morning when the winds are calmest.

Some satellites become "old friends," said Bill Mahoney, chief of the Payload Processing Division. "You meet the same people coming in, and the hardware is familiar to us. But there are definitely differences in customers—in personalities and modes of operation—and there has to be a bit of 'head-shaping' to make sure things are done properly."

Of the recent payloads carried on the shuttle, the Hubble Space Telescope was the biggest headache: "It had to be double-bagged to keep it clean," said Mahoney. "Also, we minimized other work in the building to cut down on the possibility of contamination."

Often equipment is not "human engineered" for easy repair, and the Kennedy technicians spend hours of overtime correcting a problem: "On ASTRO [a Spacelab flight originally planned for last April 1990 launch] we had to work 24 hours a day, six days a week, because the people who did the wire splicing on the point system did a relatively lousy job of it," said Mahoney. "And problems like this seem to always come up—the hardware has some problems when it comes here, and we have to solve the problems. Pretty soon, we're going to have to allocate a certain percentage of our budget just to solving unexpected problems."

The Spacelabs and scientific instrument "pallets" are even trickier to process. When not in use, Spacelab equipment is stored, like so much furniture, under static-free plastic covers in the Kennedy Space Center "High Bay" facility. "The scientific investigators first have to test their own equipment," said Tom Brakefield, deputy director of Payload Processing. The experiments are placed on racks and tested for power and so on. Racks are arranged in a row on Spacelab, so "rack-to-rack integration tests" are also done.

Spacelabs are very time-consuming to put together—a Spacelab mission with a long module and a pallet may take 18 months to fully assemble and test. "The easier ones take a minimum of six and a half months with two shifts," said Brakefield. "Last year, NASA thought of filling in Spacelabs wherever a vacancy in the shuttle schedule was left by a canceled military mission, and they wanted to turn the Spacelabs around in four months. It just couldn't be done—at least not without a lot more manpower."

In the '70s and early '80s, NASA sought to sell the shuttle on its economi-

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cal reusability and quick turnaround time, and at one time predicted a flight every two weeks. This has proven to be a mirage. The shuttle was a good concept—one worth testing—but it will never be economical or routine. The equipment is just too high-tech and too labor-intensive for a quick return to space. Refurbishing an orbiter was a mightier challenge than anybody thought. Unexpected and unwelcome twists can occur, and the workers must always be prepared to shift gears quickly.

"No matter how efficient you get, it's still going to take time—period," said payload expert Bill Mahoney.

And mishaps do happen, despite the new regulations added after Challenger. Last year one of the two shuttle canisters was badly damaged in a crane accident. A few years ago, a nose cone was being towed from one facility to another and ran into some high-tension wires; it was destroyed. More recently, one orbiter's payload doors were slightly wrenched, though not seriously damaged.

Some managers complain that the additional post-Challenger oversight and paperwork itself has had a negative effect on orbiter processing by slowing it down. "If they add one more level of oversight," confessed one manager, "all I'll be doing all day every day is going to review meetings—there won't be time for anything else."

The shuttle will never be an airliner or a truck into space. Low-tech systems, like the Soviet Soyuz spacecraft, are fairly robust and forgiving. High-tech systems, on the other hand, require more delicate and intricate work. They are subject to higher failure rates and require a more highly trained support force. Shuttle technology—the propulsion systems, the tiles, the avionics—are especially unforgiving, and it's a testimony to the skills, integrity and training of the thousands of shuttle workers that more accidents haven't happened and more lives haven't been lost.

But how many times can you refurbish, tweak, modify, replace and repair a shuttle before you have to give up on it and buy a new one?

Few people believe in the optimistic "100 flights" per orbiter that NASA used to peddle to Congress, either. But the truth is, nobody really knows. When you ask workers and managers alike, you get mostly body language: a grimace, a stroke of the chin, the squinting of the eyes, a hint of a shrug.

The elusive answer is probably not to be found in NASA testimony before Congress. A better place to look might be the employee parking lots at the Kennedy and Johnson Space Centers. Every other car is a junker, and that's a good clue. You don't have to be clairvoyant to see that these folks aren't the kind to give up on a piece of equipment easily. They tinker, they replace parts, they put up with the mechanical idiosyncracies, they fidget cleverly with this and that to keep Old Betsy running.

But they don't give up on her. Not ever. □

Alcestis Oberg wrote about space station appliances in our October 1989 issue. Her books include Pioneering Space *and* Spacefarers of the '80s and '90s.

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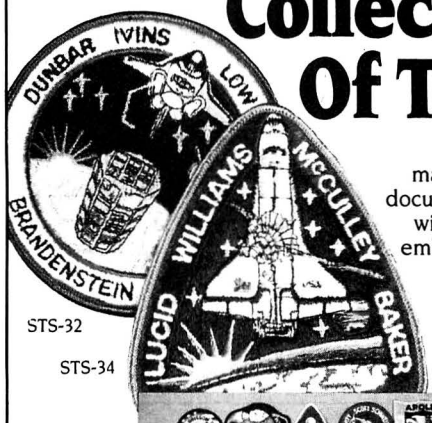

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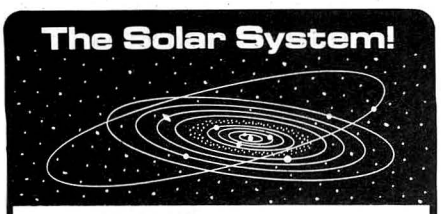

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Grassroots SETI

continued from page 53

META, which analyzes signals received by the 84-foot-diameter Harvard/Smithsonian Astrophysical Observatory Oak Ridge radio telescope. The META receiver searches eight million radio channels for a distinctive "spike" that will announce the existence of an intelligent alien civilization. META began life as a $10,000 Planetary Society project called "Suitcase SETI," a portable receiver developed by a scientific team under Paul Horowitz, now at Harvard. Just as necessity is the mother of invention, Suitcase SETI showed that federal budget cuts could lead to economical solutions.

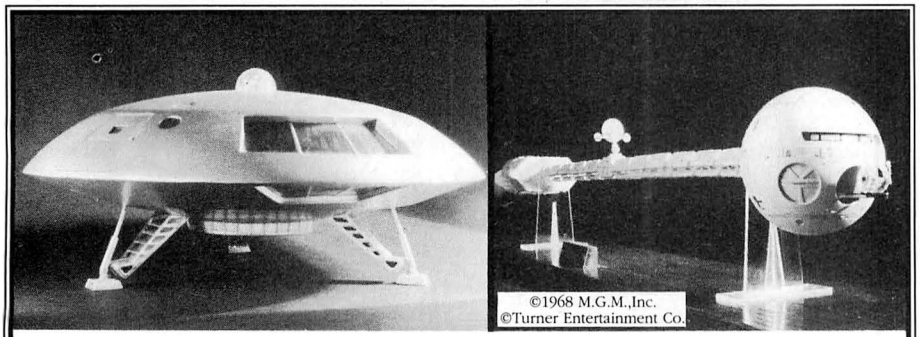
The project made its timely debut in 1981—a grim year for SETI researchers. "I attended a very gloomy meeting at NASA's Ames Research Center shortly after [former] Senator William Proxmire announced his decision to create an amendment that killed the NASA SETI Project," recalls McDonough. "Not one penny could be spent by NASA on anything connected with the search for extraterrestrial intelligence."

At that meeting, Horowitz, then at NASA Ames, described his alternative—a lightweight, 128,000-channel, mini-SETI system that could be transported to any radio observatory in the world willing to donate observing time. McDonough's ears perked up at Suitcase SETI's $10,000 price tag, and he convinced the Planetary Society to finance its construction.

Horowitz's search strategy is to scan the entire radio sky for very narrow band signals.

"You want to pick something that's distinctive and doesn't look like [background] noise," says Horowitz. Also, assuming alien civilizations have their own William Proxmires, a narrow band signal uses less energy and would be cheaper to transmit.

Although the offer of "have SETI, will travel" led to some observing time at the



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1,000-meter Arecibo telescope in Puerto Rico, Suitcase SETI eventually was installed permanently at Harvard as *Project Sentinel*. In 1985 the system was souped up, using Spielberg's donation, to create META.

"In effect, we cloned Suitcase SETI 64 times so it could now scan eight million frequencies," says McDonough.

According to Horowitz, none of the equipment required a technological breakthrough. "It did not stretch the state of the art; it was just that no one else was doing it," he says.

And until Congress appropriates the money for a more sensitive SETI system, META will be the best chance we have for finding an extraterrestrial civilization.

"We are basically challenging NASA and other government space programs," says Friedman. "When they come on line, they're going to have to do better." □

—Randall Black

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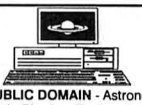

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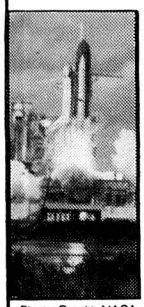

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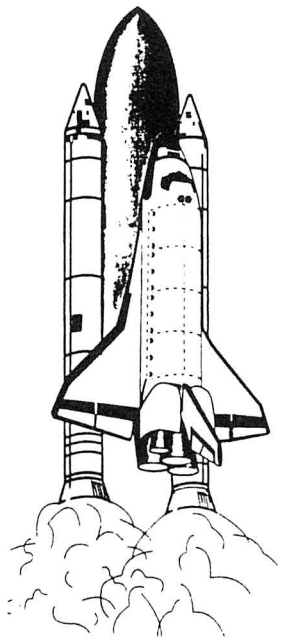

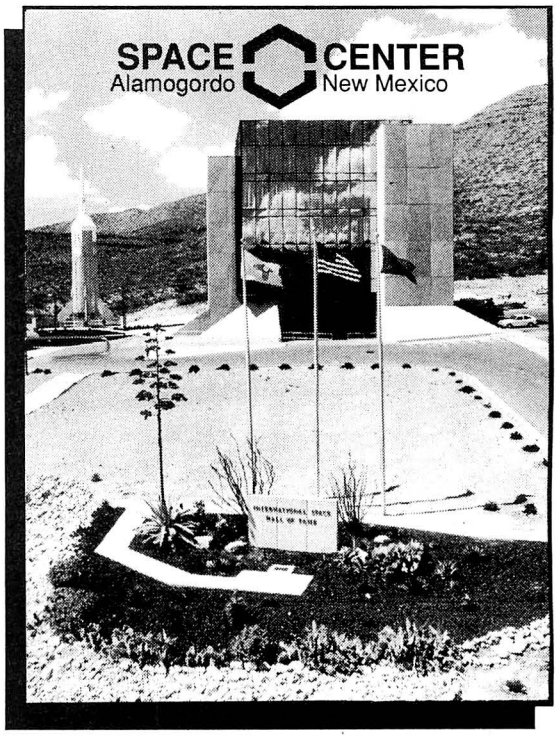

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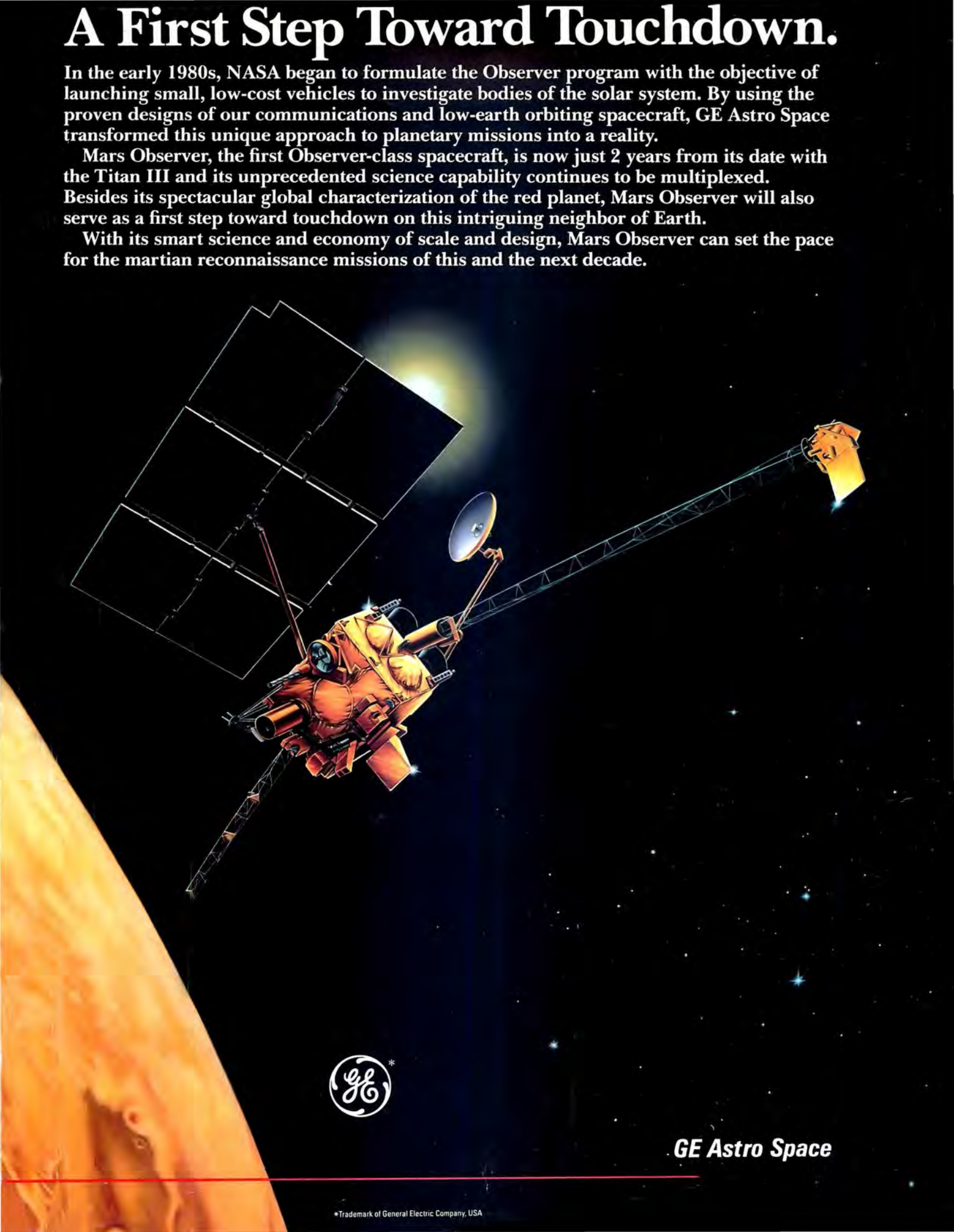

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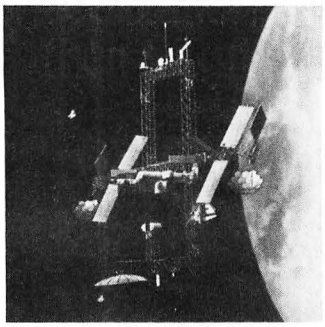

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